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MORTALITY OF NEW ENGLAND DENTISTS, 1921-1960

Robert L. Glass

Public Health Service
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Radiological Health

MORTALITY OF NEW ENGLAND DENTISTS

1921-1960

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

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MORTALITY OF NEW ENGLAND DENTISTS

1921-1960

Robert L. Glass

A report of a study performed at the Department of Epidemiology, Harvard School of Public Health, and aided by contract number SAph 76598 from the Division of Radiological Health.

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ABSTRACT

An epidemiological study was conducted to determine the mortality of dentists in comparison with that of the general population and of physicians. A cohort of 11,478 white male dentists practicing in New England from 1921 to 1960 has been identified from the records of the State licensing authorities. The age, date of entry to risk, and survivorship status of each dentist have been determined and age-distributed person-years at risk computed. Death certificates of deceased dentists have been searched and coded. Observed numbers of deaths from all and from selected causes have been compared with those expected if the cohort were subject to various standard death rates.

Leukemia mortality has approximated that expected from several sets of standard rates, both in the entire cohort and in that group entering dental practice prior to 1921. Mortality from all causes has been less than that expected from death rates of the New England white male population and U.S. physician population, but greater than that of certain medical specialists. Cancer mortality has been significantly less than, and mortality from cardiovascular diseases about equal to, that of the general population. Suicide is the only cause of death with greater than expected mortality throughout the study period. No relationship between mortality and exposure to ionizing radiation was observed.

THE AUTHOR

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Vital Statistics Offices of the New England States
Boards of Dental Examiners of the New England States
Massachusetts Dental Society
American Dental Association
  Bureau of Economic Research and Statistics
  Bureau of Membership Records

INTRODUCTION

Research involving cathode ray tubes led to the discovery of X-rays in 1895 by Roentgen (*1*). The first known dental roentgenogram was made 2 weeks later with an exposure time of 25 minutes (*2*). Ignorance of the harmful effects of X-radiation characterized early research, as pioneers in the field experimented without adequate protection. By 1898, there was evidence that exposure to X-radiation produced dermatitis. Hesse had documented, by 1911, 94 cases of carcinoma induced by exposure to X-rays (*3*). The harmful effects of X-rays upon the hematopoietic tissues were also recognized in early reports prior to 1910 (*4*).

In recent years, epidemiological evidence of a positive association between leukemia and exposure to X-radiation has been found in studies of radiologists, patients treated by X-radiation, and children exposed to diagnostic radiography *in utero* (*5–16*).

The dental profession constitutes a large group at risk of exposure to X-radiation over a long period of time. Dental X-ray machines in the United States have been estimated to number 44,000 in 1942, 65,000 in 1952, and 95,000 in 1958 (*2, 17, 18*). According to the National Health Survey, 49 million dental X-ray visits were made for the year beginning July 1, 1960, although only one-third of the U.S. population was estimated to visit a dentist each year (*19, 20*).

These findings, plus the evidence of inadequate radiological health procedures described later in this report, prompted this study of leukemia mortality among dentists.

X-RADIATION IN DENTAL PRACTICE

Dental literature prior to 1956 contains relatively few articles dealing with the harmful effects of X-radiation. Although the Harvard Dental School organized its formal instruction in roentgenology as early as 1912, some dental roentgenology departments until recently operated as service facilities without adequate radiological health teaching programs. In 1963, a conference session of the American Association of Dental Schools took cognizance of these inadequacies and recommended that each dental school establish a required course in dental radiology (*21*). Obviously, many dentists have used radiographic equipment without formal instruction in its use and associated hazards. In fact, recent studies have demonstrated ignorance on the part of some dentists concerning basic radiological safety.

One of the first analyses of radiation hazards in dental offices was reported by Nolan and Patterson in 1953 (*22*). After a study of six dentists' offices, Nolan and Patterson made specific recommendations concerning apparatus and technique to reduce observed hazards to patient and operator. Their recommendations went unheeded until the 1956 report of the National Academy of Sciencies on "The Biological Effects of Atomic Radiation" (*23*). From a practical standpoint, the control of radiation hazards in dental offices started only after the publication of this report.

The outcome of the 1956 National Academy of Sciences' publication was rare in the field of public health. Ordinarily, a health problem attracts public health attention only after considerable mortality, morbidity, or economic loss. This has not been the case in the field of radiological health. The total number of deaths directly due to exposure to ionizing radiation in the United States has been less than the number of fatalities resulting from automobile accidents occurring during a single weekend (*24*). However, the potential health hazards from existing and projected uses of ionizing radiation justify extensive radiological health precautions.

The 1956 publication of "The Biological Effects of Atomic Radiation" stimulated a series of examinations of dental X-ray installations throughout the United States. In a survey of 122 dental X-ray machines in Chicago in 1958, Yale and Hauptfuehrer (*25*) found that:

1. The average age of the machines surveyed was 11.6 years.
2. 22.6 percent were collimated.
3. 16.8 percent had added filtration.
4. The average operator-to-patient distance was about 5 feet.
5. Machines in the 11–15-year-old age group had the highest relative roentgen output.
6. Many dentists were receiving more than the maximum permissible dosage rate.
7. Many dentists were "safe" only due to limited use of their X-ray machines.

In 1959, about 2,000 X-ray machines in dental offices in 10 States were monitored (*26*). Dentists participated on a voluntary basis, with 44 percent of those queried requesting that their offices be included. This extensive investigation revealed that 70 percent of the machines inspected were collimated and 55 percent had added filtration.

As late as 1963, Miller found that 36 percent of dental X-ray machines tested by the Surpak survey had beam diameters greater than the maximum permissible limit of 3 inches and 29 percent had less than 1.5 millimeters of aluminum equivalent filtration (*27*).

Tables 1 and 2 show the results of monitoring 800 dental radiographic installations in Massachusetts by Scavotto *et al.* (*28*). Each installation was checked, with the voluntary participation of the dentists, by an engineer of the Massachusetts State Health Department. In each of these tables, the data from the first 100 units surveyed in 1958, the last 100 surveyed in 1959, and the total are tabulated separately. Table 1 shows the operational characteristics of the 800 units surveyed. The inspection team, on the basis of its findings, finally refused to monitor certain types of X-ray machines because of known exposure hazards in their use. Therefore, if all units had been checked, the radiation hazard would have appeared greater. Table 2 shows the distribution of estimated machine operator dose per week. These estimates are based upon the survey values, plus average weekly film load and operator position during exposure. Scavotto's survey was accompanied by an extensive educational program on the part of the Dental Division of the Massachusetts Department of Public Health and the State Dental Society. It is interesting to note the improvement in operating conditions, tables 1 and 2, between the first and last groups of units surveyed.

Table 1. Operating characteristics of 800 dental X-ray units in Massachusetts, 1958–59 [a]

Operating characteristics	100 units 1958	800 units 1958–59	100 units 1959
Operated <70 kV	98%	89%	86%
Filter <1.5 mm [b]	40%	39%	25%
Inadequate collimation	58%	40%	34%
Relative film speed	3.2	4.0	5.1
Mean R's per exposure	4.6	2.5	1.7
Range, R's per exposure	.3–12.3	.09–15.5	.1–13.6

[a] Reference *28*.
[b] Aluminum equivalent.

Table 2. Estimated machine operator dose based upon surveys of 800 dental X-ray units in Massachusetts, 1958–59 [a]

Distribution of machine operator dose in mR per week	100 units 1958 (percent)	800 units 1958–59 (percent)	100 units 1959 (percent)
0.01– 29	65	76	77
30 – 49	9	10	8
50 – 99	13	9	12
100 –850	13	5	3

[a] Reference *28*.

In a survey of dental practice conducted by the American Dental Association, detailed information was obtained concerning dental X-ray machines and their operation. It was estimated that 81,000 dentists owned 95,000 radiographic units in 1958. Four percent did not own a unit, and some dentists owned more than one. Tables 3–6 are taken from the report of this survey (*18*). The average age of all dental X-ray machines in the United States was about 10 years, table 3. The mean age of X-ray machines in New England was almost 2 years greater than the U.S. average. To offset purchases of new equipment by recent graduates, many old machines were in use. Generally speaking, newer equipment can be operated with less hazard.

Table 4 shows the distribution of timer-cord lengths. The length of the timer cord determines the maximum distance that the machine operator can stand from the unit while in use. Fifteen percent of the machines had timer cords less than 6 feet in length.

Table 5 shows that about 70 percent of the dentists used fast film, and 23 percent medium or slow film. Obviously, the faster the film, the lower are the exposure required and the attendant risk of exposure to the operator. The percentage of "no answer" increased with increasing age of the dentists.

Table 6 shows that 10 percent of the machines at the time of the survey were not properly collimated. Collimation confines the X-ray beam to a restricted solid angle by means of a lead diaphragm. Without this diaphragm, the beam diameter is greater than that of the useful beam, resulting in unnecessary radiation to patient and operator alike. Dental radiographic technique is relatively simple; however, without the lead diaphragm, the solid angle of the X-ray beam is much larger, making it difficult to miss the film during an exposure.

About 10 percent of the sample queried in the above American Dental Association survey replied "occasionally" to the question: "Do you ever hold the film in the patient's mouth while the X-ray is being taken?" The affirmative reply "occasionally" came largely from the older-age groups. Another question in the survey was: "Have you ever developed an X-ray burn on your fingers?" A total of 1.7 percent replied in the affirmative. No dentist under 30 years of age, although nearly 5 percent of dentists over 60 years of age, admitted to having developed X-ray burns. Those with such burns had used dental radiographic equipment, on the average, for 14 years.

The preceding surveys document the earlier deficiencies of dental X-ray equipment and inadequate radiological safety procedures of some dentists. However, these reports only provided estimates of machine operator X-radiation dose based upon survey findings and estimated film load. Table 7 shows the results of a film badge survey conducted in 1956 in the Boston area (*29*). Although only 11 dentists participated, their mean weekly

Table 3. Mean number and age of dental X-ray machines by region of the United States, 1958 [a]

Region	Mean number of machines	Mean age of machines (years)
New England	1.3	11.5
Middle East	1.2	10.7
Southeast	1.2	8.1
Southwest	1.3	7.8
Central	1.1	10.3
Northwest	1.1	8.7
Far West	1.2	8.3
United States	1.2	9.6

[a] Reference *18*.

Table 4. Percentage distribution of X-ray machines according to length of timer cord, United States, 1958 [a]

Length in feet	Percent
3	1.0
4–5	13.9
6–7	33.8
8–9	13.1
10–14	16.6
15–19	6.1
20–	2.4
No answer	13.1

[a] Reference *18*.

Table 5. Percentage distribution of dentists according to speed of X-ray film used, by age of dentists, United States, 1958 [a]

Age	Speed of film			No answer	Total
	Slow	Medium	Fast		
-29	2.0	25.4	71.0	1.6	100.0
30-34	0.6	22.8	72.3	4.3	100.0
35-39	0.9	21.5	71.4	6.2	100.0
40-44	0.5	22.3	71.0	6.2	100.0
45-49	1.3	21.5	73.7	3.5	100.0
50-54	1.4	23.5	66.9	8.2	100.0
55-59	1.3	20.7	68.5	9.5	100.0
60-64	1.7	20.7	66.1	11.5	100.0
65-	0.4	20.8	59.6	19.2	100.0
All ages	1.0	22.3	69.9	6.8	100.0

[a] Reference *18*.

Table 6. Percentage of X-ray machines having lead diaphragms (collimation), by age of dentist, United States, 1958 [a]

Age	Percentage of machines having collimation			
	Yes	No	No answer	Total
-29	74.4	7.1	18.5	100.0
30-34	72.2	8.7	19.1	100.0
35-39	71.1	8.3	20.6	100.0
40-44	64.2	11.9	23.9	100.0
45-49	59.2	12.4	28.4	100.0
50-54	61.5	10.0	28.5	100.0
55-59	51.4	9.4	39.2	100.0
60-64	50.5	12.3	37.2	100.0
65-	42.0	7.1	50.9	100.0
Total	64.1	9.6	26.3	100.0

[a] Reference *18*.

dose was in excess of that of radiologists. From 1950 to 1958, Spalding and Cowing conducted a film badge survey of dentists and dental assistants operating X-ray equipment in 236 dental offices and clinics (*30*). The results of this 9-year study are shown in table 8. Over one-third of those monitored received average exposure in excess of 0.1 roentgen per week. From 1950 to 1955, 3–6 percent showed an average exposure in excess of 0.3 roentgen per week. The authors concluded that dental personnel had greater X-ray exposure as a result of their normal work routine than did others utilizing X-radiation for diagnostic purposes.

Table 7. Results of a Boston film badge survey (cited by Warren 1956)[a]

Specialist	Mean weekly dose (mR)
Radiologists (no fluoroscopy)	40
Radiologists (fluoroscopy)	180
Dentists	200
Dermatologists	250
Urologists	470

[a] Reference *29*.

Table 8. Percentage distribution of dental X-ray machine operator dose in roentgens per week, 1950–58 [a]

Operator dose in roentgens per week	Percentage by year								
	1950	1951	1952	1953	1954	1955	1956	1957	1958
0–.009	14	12	10	12	13	10	8	14	11
.010–.099	40	49	55	55	54	50	65	49	56
.100–.199	24	23	21	19	19	28	18	27	23
.200–.299	18	10	9	11	10	9	7	8	9
.300+	4	6	5	3	4	3	2	2	1

[a] Reference *30*.

Dental X-ray machines are generally operated within the range of 45–95 kilovolts. The use of machines with the higher kilovoltages started around 1950. When dental X-ray machines came into widespread use during 1930–50, the kilovoltage ranged from 45 to 55. The kilovoltage is an important factor in determining the amount of radiation to which the operator and patient are exposed. If all operating characteristics are held constant, an increase in kilovoltage results in an increase in both primary and secondary radiation. However, the increased penetrability of harder X-rays generated at higher voltages makes possible a decrease in the quantity of radiation necessary for proper film exposure. The reduction in quantity of radiation results in a decrease in secondary radiation. Independent surveys of dental X-ray equipment in 1958 and 1959 demonstrated that the average age of X-ray machines was about 10 years, and that 30 to 40 percent were not collimated. These facts support the findings of film badge surveys discussed above.

METHOD

DESIGN OF THE STUDY

The purpose of this investigation was to study the mortality of dentists and compare it with that of the general and physician populations. The specific hypothesis to be tested was that mortality from leukemia for dentists was greater than for the general population, due to the use by the former of X-ray equipment and its associated risk of X-ray exposure over a long period of time. Since it was necessary to search all death certificates to find leukemia deaths among deceased dentists, the aim of the study was extended to include mortality from all and selected causes of death.

The male white dentists eligible to be included in this study were those who practiced in the New England States between 1921 and 1960. The 40-year period of observation was utilized to permit evaluation of secular changes in leukemia mortality during the period that dental X-ray equipment came into widespread use.

Mortality was evaluated by assembling the names of those dentists eligible for inclusion, determining their year of birth, and entry to risk as well as survivorship, and identifying each death by date and cause. The deaths observed were compared with those expected from the products of age-distributed person-years at risk and appropriate standard rates. Results were analyzed by standardized mortality ratios and standard tests of significance for sequential and selected 5-year periods.

ASSEMBLY OF THE STUDY COHORT

The preliminary group for assembly purposes was defined as those dentists listed under New England States in the 1917 Polk Dental Directory (*31*). To this list were added new names from the 1925 and 1928 editions (*32, 33*). The composite listing from these commercial directories was expanded by the addition of new names from selected directories published by the American Dental Association (*34–37*).

During the study period, more than one-half of New England dentists practiced in Massachusetts. Therefore, the above cohort membership was further enlarged from a review of the membership records of the Massachusetts Dental Society.

Laws regulating the practice of dentistry were enacted in all New England States prior to 1900. By 1921, all States except Massachusetts, New Hampshire, and Vermont required annual registration for license renewal. Massachusetts required triennial rather than annual renewal until 1928; New Hampshire and Vermont adopted annual registration around 1930. State records of licensure and renewal were used to determine final eligibility for inclusion.

All the records of each New England dental licensing authority were reviewed. The purpose of this search was twofold. First, the preliminary list of practicing dentists prepared from directories was checked against official records to make the cohort membership complete and accurate. Second, additional data basic to the study were secured at the same time. The names of those dentists included on the preliminary listings, but not showing evidence of dental practice from 1921 on, were deleted. Additional names, absent from the directories, were added on the basis of State records.

In order to be included in this study, a dentist must have had a license to practice in a New England State, been male and white, and shown evidence of dental practice in New England between 1921 and 1960. Proof of licensure was obtained from records of the individual States as discussed above. Some dentists listed in available commercial directories were not licensed and thus not included. Sex and race were established from State records, death certificates, photographs, and inquiry.

Records of cohort members were maintained on punch cards to facilitate repeated updating and analyses by computer. The following information was coded:

- Name
- State of origin
- License number
- Year of birth
- Year of entry to practice in New England [1]
- Survivorship status
    - Alive at end of study
    - Deceased during study
    - Lost to trace
    - Deceased after end of study
- Year of death or loss to trace, if pertinent.

---

[1] Until 1940 almost all dentists who ever practiced in New England started practice immediately after licensure. After 1940, service with the Armed Forces, internships, and post-graduate study often delayed entry into practice.

The year of death or year lost to trace served as exit dates from risk. These subjects were no longer included in person-years at risk calculations beyond that exit date. The exit date assigned for untraced dentists was the last year the individual was known to be alive. Usually this was derived from the last year of payment of a license renewal fee or from correspondence. In the first 10 years of the study, the exit date had to be based on the Polk Dental Directories for certain dentists from Massachusetts, New Hampshire, and Vermont. In the case of inclusion in one directory and not in the next, or in one triennial registration (Massachusetts), and not in the next directory, a year midpoint between the two was assigned as the exit date.

Members of the Army, Navy, Air Force, and U.S. Public Health Service were not included unless New England private practice preceded their Federal service. Dental school teachers licensed to practice, as defined above, were included. Once eligible for membership in the study, a dentist remained at risk throughout the study until dead or "lost to trace."

PROOF OF SURVIVORSHIP

The largest single group of cohort members was one which had renewed licenses in 1961 by the payment of a renewal fee. This information was obtained by searching records of the various licensing boards of the New England States. This group was presumed to be alive.

Dentists retired from active practice and those residing outside of New England were mailed a questionnaire about New England practice with a printed, stamped return postal card on which the dentist was requested to write his year of birth and year of entry into dental practice in New England. These two dates provided a reason for sending the inquiry, that is, a check on data secured locally; and if returned, evidence of being alive in 1961 when their mailing was started. Some of these forms were returned by the post office marked "deceased" or "unknown." Some were returned by families or attorneys marked "deceased," occasionally with the date and place of death. In such cases, the death certificates were then searched in the State of last residence. An attempt was made to secure new addresses for those returned "unknown" or "moved" from:

1. Latest American Dental Association directories
2. University Alumni Association files
3. State Dental Society records
4. Dental School classmates
5. Practice associates.

When mail survey failed, the subject was coded "lost to trace" with an exit date corresponding to the last year known alive.

Death certificates were searched and copied for those dentists known to have died during the study period. Special 5- by 8-inch cards were printed to receive this information copied in State Vital Statistics offices. A reproduction of the form used is shown in figure 1. In some instances, the exact date and place of death were known. Often only the fact that a man was deceased was known, in which case death indexes were consulted from the year last known alive to the present to find the death certificate. Photostatic copies of death certificates for those deaths occurring outside of the New England and New York areas were obtained. All untraced individuals were searched in the appropriate New England State Vital Statistics Death Indexes from the year last known alive to the present.

Cohort members who died after December 31, 1960, were counted alive at the end of the study period in person-years at risk calculations. Newsclipping services, as well as information from dental societies and licensing boards, helped complete knowledge of the status of this group. The mail questionnaires described above were occasionally returned marked "deceased" and provided the initial data for inquiry in this direction.

CODING PROCEDURES

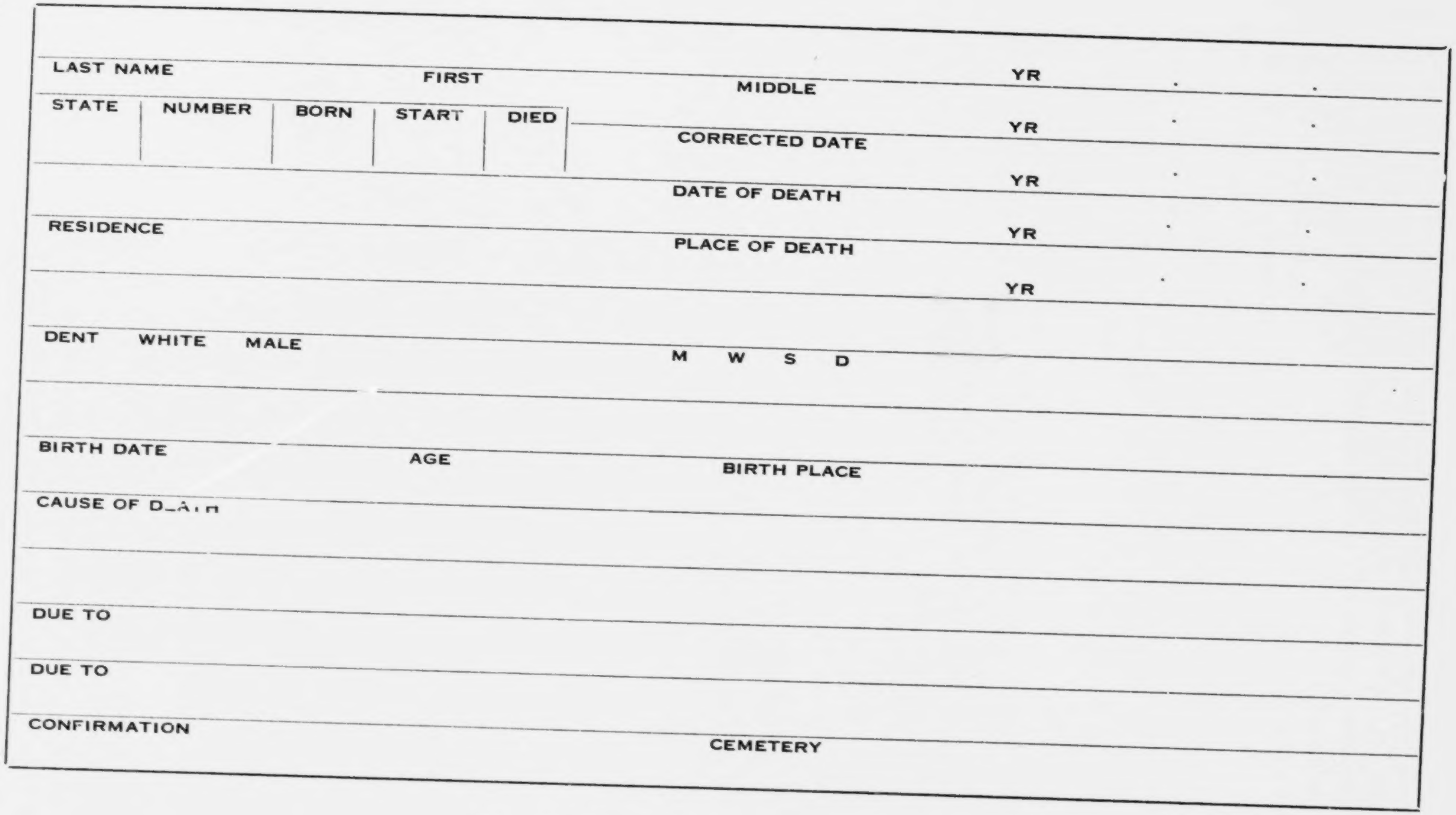
Extending from 1921 to 1960, this study covers a time span in which five International Cause of Death Classifications were used (*38–45*). The various revisions and the years in use are shown in table 9.

Table 9. Periods of use of selected Revisions of the International List of Causes of Death [a]

Revision	Year	Period of use	Joint Manual Edition
3	1920	1921–29	2
4	1929	1930–38	3
5	1938	1939–48	4
6	1948	1949–57	—
7	1955	1958–	—

[a] References *38–45*.

In New England, the Third Revision was used through 1930. Otherwise, the appropriate Revision was used to code deaths of cohort members occurring within the period of time that the Revision was in use. This enabled deaths of dentists occurring throughout this study to be coded by the same method in use at the time of the deaths. Through this pro-



LAST NAME FIRST MIDDLE YR . .

STATE | NUMBER | BORN | START | DIED

CORRECTED DATE YR . .

DATE OF DEATH YR . .

RESIDENCE

PLACE OF DEATH YR . .

YR . .

DENT WHITE MALE M W S D

BIRTH DATE AGE BIRTH PLACE

CAUSE OF DEATH

DUE TO

DUE TO

CONFIRMATION CEMETERY

Figure 1. Form used to copy death certificates

cedure, cause-of-death comparisons may be made now with cause-of-death data published in the past. When multiple causes of death appeared on the death certificate from 1921 through 1948, all causes were coded and the death assigned to the code given priority by the appropriate Joint Cause Manual.

In selected cases, individual causes of death were grouped for analysis: for example, heart disease, pneumonia and influenza. In certain 5-year periods, two different International Revisions were involved. The category numbers grouped under these conditions were the same as those combined by the National Office of Vital Statistics (*46*). These are detailed in table 10.

Table 10. Causes of death included according to International Revision and Title Number

Cause of death	International Revision Number			
	3	4	5	6 and 7
Leukemia	65a	72a	74a, b	204
Malignant neoplasms	43-49	45-53	45-55	140-205
Heart disease	87-90	90-95	90-95	410-443
Vascular lesions CNS	74, 75, 83	82	83	330-334
General arteriosclerosis	—	97	97	450
Chronic nephritis	129	131, 132	131, 132	592-594
Tuberculosis—all forms	31-37	23-32	13-22	001-019
Influenza and pneumonia	11, 100, 101	11, 107-109	33, 107-109	480-493
Ulcer of stomach and duodenum	111	117	117	540, 541
Cirrhosis of liver	122	124	124	581
Diabetes mellitus	57	59	61	260
Accidents	176-189 192-196 201-203	176 178-195 201-214	169-176 178-195 —	E800-E802 E810-E835 E840-E962
Suicide	165-174	163-171	163, 164	E963 E970-E979

PERSON-YEARS AT RISK

Person-years at risk were used to calculate expected numbers of deaths. Such a procedure was essential because of changes in numbers of cohort members owing to varying rates of entry and exit. Person-years at risk were compiled for 5-year periods for 5-year-age brackets according to the following method. A dentist at risk prior to and beyond a 5-year interval contributed 5 person-years at risk in that 5-year period. A dentist entering the cohort during a 5-year period and still at risk beyond the end of the period was assumed to have entered at midpoint and contributed 2½ person-years at risk. One at risk prior to the beginning of a 5-year period and dying or lost to trace during the period also contributed 2½ person-years at risk. A member entering and leaving the cohort during the same 5-year period contributed 1¼ person-years at risk. In each of the conditions described above, when a member's age changed age brackets during a 5-year period (for example, from 20–24 to 25–29), the change was assumed to have taken place at the midpoint of the period and one-half of his person-years at risk were assigned to each appropriate age bracket.

Person-years at risk of the cohort were calculated from the completed punch card file by means of a specially written computer program. The program was originally written to calculate person-years at risk, entries, and exits for 5-year intervals ending in 5 and 0. It was revised to permit computations for 5-year periods ending in 8 and 3. This revision permitted the use of published death rates in more appropriate time intervals.

COMPARISON GROUPS

No control group has been assembled and studied in the same manner as the study cohort dentists. In order to effect comparisons, rates for New England white males were formulated to compute the number of deaths expected in the cohort of dentists if they were subject to the same age-specific death rates. Comparisons were also made using actual rates specific to New England, published by the National Office of Vital Statistics for certain time periods. Published death rates for physicians were also used to calculate standard deaths for comparisons.

Age and cause-specific death rates for New England were calculated in the following manner. The number of white male deaths from all and selected specific causes of death was tabulated for New England States for each year (1921-60), by each 5-year-age bracket, 20 years of age and over. These mortality data have been published by the Federal Government by age, sex, and race since 1937 (*47*, *48*). Prior to 1937, mortality data except for all causes were not listed specifically by age, sex, and race for each State. Therefore, from 1921 to 1936, New England cause-specific death rates were calculated from numbers of deaths obtained from publications of the individual States. In addition, some cause-specific rates from 1936 to 1948 were derived from data from State Vital Statistics records (*49–53*). The deaths from each State were added for each 5-year period for each age bracket and divided by 5 to obtain an average annual number of deaths for the New England white male population for each adult 5-year-age group. Table 11 shows, by cause and year available, the sources of data from which New England rates were calculated. Data for deaths from all causes were obtained from national sources for all years.

From the U.S. Censuses of 1920–60, the numbers of white males for each age bracket, age 20 and above, for New England were estimated

Table 11. Sources of cause specific mortality data for comparisons, 1921–59

Cause	Source of data [a]			
	1921–30	1931–35	1937–48	1949–59
Tuberculosis	s	s	n	n
Influenza and pneumonia	s	s	n	n
All malignant neoplasms	s	s	n	n
Malignant neoplasms of:				
Buccal cavity	s	s	s	n
Digestive organs	s	s	s	n
Respiratory system	–	s	s	n
Leukemia	s	s	s	n
Heart disease	s	s	n	n
General arteriosclerosis	–	s	s	n
Vascular lesions affecting CNS	s	s	s	n
Chronic nephritis	s	s	n	n
Diabetes mellitus	s	s	n	n
Ulcer of stomach and duodenum	s	s	n	n
Cirrhosis of liver	s	s	n	n
Suicide	s	s	n	n
Accidents	s	s	n	n

[a] Source of data:
s = State data
n = U.S. Government data
– = not coded

for the midpoints of the periods 1921–25, 1926–30, 1931–35, 1936–40, 1941–45, 1946–50, 1951–55, and 1956–60 (*54*). These midpoint estimates were divided into the appropriate 5-year average numbers of deaths to obtain average age, time, and cause-specific death rates.

State Vital Statistics reports have not always provided separate enumeration of white and nonwhite deaths by cause. Therefore, rates based upon data from State reports may be somewhat higher than the actual rate due to the inclusion of nonwhite deaths. The extent to which the above cause-specific rates may be affected due to the inclusion of nonwhite deaths in the numerator of death rates may be estimated from the population and number of deaths of nonwhites in New England. Less than 2 percent of the New England male population have been nonwhite. Nonwhite males, age 20 and older, range from 1.4 percent in 1920 to 1.6 percent in 1950 of all males of these ages (*54*). Nonwhite male deaths, age 20 and over, are shown to average about 1.7 percent of all male deaths, table 12, for the midpoint years of successive 5-year periods. Therefore, the expected deaths from New England standards in certain years may be overestimated by about 1.7 percent. As noted previously, this factor does not apply to deaths from all causes or most causes of death from 1937 to 1960.

Table 12. Nonwhite male deaths expressed as a percent of all male deaths over age 20 for selected years [a]

Year	Percent nonwhite male deaths
1923	1.7
1928	1.8
1933	1.8
1938	1.7
1943	1.7
1948	1.7

[a] References *47, 48*.

The National Office of Vital Statistics has published death rates for selected causes by age, color, and sex for the periods 1940 and 1949–51 (*55, 56*). These rates were specific for the New England region and were also utilized to compute expected deaths. The person-years at risk computer program was altered to compute person-years at risk for the periods 1939–43 and 1949–53. This adjustment made the midpoint of the effective period of the published rates only 1 year earlier than the midpoint of the period of person-years at risk.

Death rates for U.S. physicians have been published by Emerson and Hughes for 1925 (*57*), Dublin and Spiegelman for 1938–42 (*58*), and Dickinson and Martin for 1949–51 (*59*). Death rates for U.S. physicians and dentists have been published by the National Vital Statistics Division of the U.S. Department of Health, Education, and Welfare (*60–62*). Death rates for various physician specialty groups have been recently calculated by Seltser and Sartwell (*63, 64*). These published rates have been used to predict expected numbers of deaths for comparison with those observed.

ANALYSIS

Results were analyzed by use of the standardized mortality ratio (S.M.R.). A standardized mortality ratio may be defined as the number of deaths observed in a group, expressed as a percentage of the number of deaths expected in that group if it were subject to a standard set of mortality rates. Thus,

$$\text{S.M.R.} = 100 \times \frac{\text{number of observed deaths}}{\text{number of expected deaths}}.$$

The number of expected deaths may be calculated from death rates of the general population or some other comparison group.

Kilpatric (*65*) has shown that the number of observed deaths divided by the square of the number expected provides a "slightly overestimated" variance of the ratio. This is the same as the approximation suggested by Yule (*66*), and used by the Registrar General of England and Wales and the National Vital Statistics Division of the U.S. Public Health Service. The formula for the standard error of the S.M.R. becomes

$$\text{S.E.}_{\text{S.M.R.}}=\frac{100\sqrt{\text{number of observed deaths}}}{\text{number of expected deaths}}.$$

The standard error of a difference between the observed S.M.R. and 100 percent is as follows:

$$\text{S.E.}_{\text{S.M.R.}-100}=100\sqrt{\frac{\text{Observed}_1}{\text{Expected}_1^2}+\frac{\text{Observed}_2}{\text{Observed}_2^2}},$$

where the subscripts 1 and 2 stand for sample and standard, respectively The second term may be neglected because it contributes so little when the observed value (from the standard) exceeds 10. In fact, Chiang states that random variations in the standard age-specific rates should not be included in the variance of the adjusted rates (*67*). In this study, expected deaths were calculated from standard rates derived from New England and physician populations. Rates for the New England population were based upon such large numbers that the second term in the standard error of the difference between 100 percent and an S.M.R. is negligible. The death rates of physician specialty groups used as standards were based on numbers of deaths ranging from 171 to 725. Therefore, the standard error of the S.M.R. was also used as an estimate of the standard error of the difference between the S.M.R. and 100 percent, following the practice of official mortality reports of the United States and England (*60–62, 68, 69*).

The difference between 100 percent and a standardized mortality ratio may be substituted in the formula $Z=\frac{X-\mu}{\sigma}$. Here, μ equals 100 percent, the expected value of the general population or standard, and

$$Z=\frac{\left(100\frac{\text{observed}}{\text{expected}}\right)-100}{100\frac{\sqrt{\text{observed}}}{\text{expected}}}=\frac{\text{observed}-\text{expected}}{\sqrt{\text{observed}}}.$$

Z is a scale value of the standard normal distribution. This value may be used to enter tables of area under a normal curve to determine probability.

Comparisons of two independent standard mortality ratios utilized the following formula for the standard error of the difference between two ratios:

$$\text{S.E.}_{\text{S.M.R.}_1-\text{S.M.R.}_2}=\sqrt{\frac{(\text{S.M.R.}_1)^2}{\text{Observed}_1}+\frac{(\text{S.M.R.}_2)^2}{\text{Observed}_2}}.$$

One of the disadvantages in utilizing person-years at risk as a denominator is their interrelationship. The person-years at risk derived from one cohort member are more similar in nature than an equal number contributed by as many individuals. This lack of independence tends to provide an underestimate of the variance. No allowance can be made for this interrelationship since it cannot be evaluated. Interdependence is usually absent when standard statistical analyses are performed. However, if death rates are relatively small, the objection becomes a minor one.

COHORT DESCRIPTION

SIZE AND SECULAR CHANGES

A total of 11,478 dentists was certified as having practiced in New England from 1921 to 1960. Table 13 shows the survivorship status of study members by State. All except 368 dentists, or 3 percent of the total, were traced through the end of the study. Changes in strength of the cohort are shown in table 14, along with numbers of entries, exits, deaths, and person-years at risk according to 5-year periods. Table 14 suggests that there were 1,784 more dentists in New England in 1960 than

Table 13. Summary of status of cohort members

Status at end of study	State						Total
	Mass.	R.I.	Conn.	Maine	N.H.	Vt.	
Alive 1961 [a]	3,215	433	1,798	382	268	163	6,259
Died during study	2,381	295	706	312	193	134	4,021
Alive 1961 [b]	429	63	54	55	24	18	643
Died after study	106	19	28	17	8	9	187
Untraced	202	30	72	44	7	13	368
Total	6,333	840	2,658	810	500	337	11,478

[a] Paid 1961 license renewal fee.
[b] Alive per postal survey.

Table 14. Changes in strength of the cohort, 1921–60

Year	Number at start	Entries	Exits	Lost to trace	Deaths	Person-years at risk	Number at end	Net gain
1921–25	5,301	837	284	24	260	27,907	5,854	553
1926–30	5,854	571	416	105	311	29,671	6,009	155
1931–35	6,009	519	510	45	465	30,082	6,018	9
1936–40	6,018	644	558	52	506	30,307	6,104	86
1941–45	6,104	440	554	36	518	30,236	5,990	−114
1946–50	5,990	1,296	607	38	569	31,664	6,679	689
1951–55	6,679	878	699	37	662	33,827	6,858	179
1956–60	6,858	988	761	31	730	34,820	7,085	227
Total	—	6,173	4,389	368	4,021	248,514	—	—

in 1921. However, a study of this type permits exits only by death or "lost to trace," not by retirement. Furthermore, there are included dentists once practicing in New England and removed to other areas. Actually, the net gain of dentists under age 65 was about 500 during the period 1921–60.

ADEQUACY OF COHORT ASSEMBLY

Failure to include appreciable numbers of eligible members may affect mortality comparisons. The completeness of the cohort may be determined by comparing its numbers in various years with previously published statistics concerning New England dentists. The U.S. Public Health Service has determined the numbers of practicing dentists in New England for selected years (*70, 71*). For corresponding years, the numbers of cohort members have been calculated by adding one-half of the entries and exits for that year to the number alive at the end of the previous year. For manpower purposes, the U.S. Public Health Service is concerned with numbers of practicing dentists. This study includes all dentists once entered into risk. In order to evaluate the adequacy of cohort assembly, a conservative approach is to compare cohort members under age 65 with U.S. Public Health Service statistics. The number of dentists under age 65 may be considered an underestimate of those dentists in practice. This comparison is shown in table 15.

The U.S. Public Health Service counts do not specify age nor do they exclude female and nonwhite dentists. Even with these limitations, the number of cohort members under age 65 exceeds Federal counts for dentists in practice for all years listed except 1920.

The Polk Dental Directories provide another source of data (*31–33*). Unfortunately, the years that information is available do not coincide

Table 15. Number of New England dentists: comparison of data from U.S. Public Health Service with cohort members under age 65 [a]

Year	Number of dentists	
	U.S.P.H.S.	Cohort <age 65
1920	5,178	5,140
1930	5,584	5,605
1940	5,038	5,345
1950	5,503	5,590
1955	5,420	5,632

[a] Reference *70*.

with the enumeration years of the U.S. Public Health Service. These estimates of numbers of dentists in New England, along with the data from this study, are shown graphically in figure 2.

All three sources show similar numbers and pattern of increase until 1930. Beyond 1928 no Polk Dental Directory was published. Federal figures fall sharply from 1930 to 1940. The numbers from this study level off but do not drop. This difference is readily explained. No exits are allowed from this study, except cohort members who are deceased or lost to trace. The U.S. Public Health Service is concerned with a count of dentists in practice. Dentists retired or removed from practice for military service are included in the cohort count. They are excluded from any enumeration of dentists in active practice.

Although U.S. Public Health Service and Polk data include female and nonwhite dentists, the actual count of white male dentists in this study exceeds numbers from other sources. This suggests that the assembly of the cohort from a practical standpoint is complete.

AGE DISTRIBUTION

The age distribution of the cohort is shown in table 16. In a study of this type, where no exits except deaths and lost members are permitted, one would expect the age distribution to change. Table 16 shows a marked shift in age distribution toward older ages in later years of the study. In the 1920's, 16 to 22 percent of the cohort members were in the under age 30 group, and only 6 percent were over age 65. After 1950, 5 to 6 percent were under age 30, but more than 20 percent were over age 65. Table 17 shows in detail age-distributed person-years at risk,

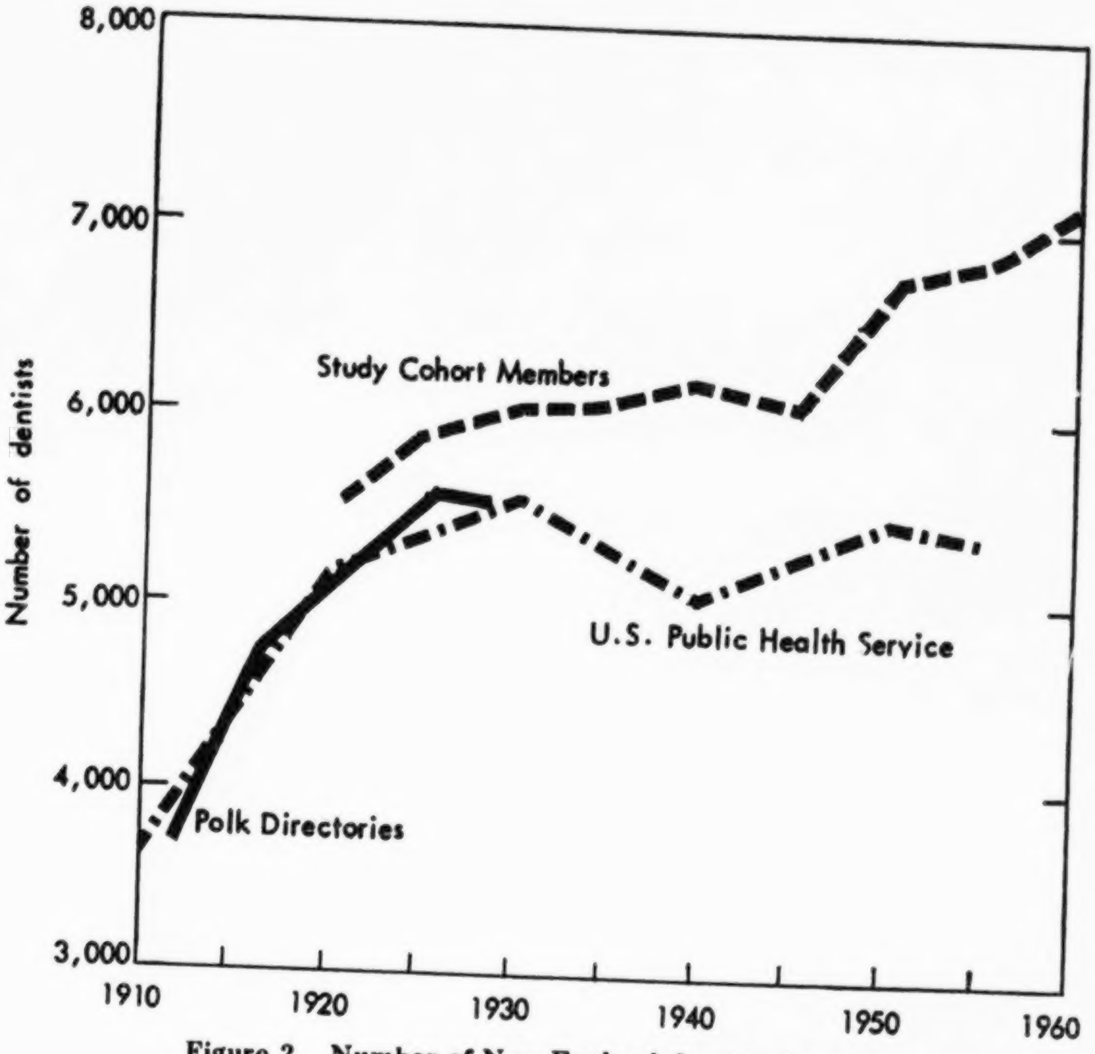


Figure 2. Number of New England dentists by year

Table 16. Percentage age distribution of New England white male dentists, 1920–60

Year	Percentage by age													
	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85+
1920	5.7	16.4	15.9	12.9	13.5	11.4	8.3	5.5	3.9	3.1	2.1	0.9	0.2	0.2
1925	2.6	13.5	16.7	15.0	11.9	12.1	10.1	7.1	4.4	2.9	2.2	1.0	0.4	0.1
1930	1.3	8.3	14.4	16.2	14.2	11.3	11.0	9.1	6.2	3.7	2.1	1.4	0.6	0.2
1935	0.7	6.5	9.9	14.2	16.0	13.5	10.4	10.1	8.1	5.2	2.8	1.4	0.9	0.3
1940	0.7	7.6	8.6	9.9	13.7	15.2	12.5	9.1	8.7	6.8	4.0	1.9	0.8	0.5
1945	0.9	4.1	9.5	9.0	10.1	13.6	14.9	11.7	8.4	7.8	5.3	2.9	1.2	0.6
1950	0.5	8.4	11.5	10.6	8.3	9.0	12.0	12.4	9.4	6.5	5.4	3.5	1.7	0.8
1955	0.2	4.9	13.9	12.7	10.5	8.0	8.6	10.9	10.8	7.7	5.0	3.6	2.1	1.1
1960	0.1	6.0	10.6	14.3	12.4	10.1	7.6	8.0	9.4	9.0	5.9	3.3	2.1	1.2

Table 17. Cohort person-years at risk, entries, and exits, by age and 5-year periods, 1921–60

Year	Category	Number by age														Total
		20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85+	
1921–25	Entries	405	302	77	28	12	6	5	1	1	0	0	0	0	0	837
	Exits	0	6	17	10	15	25	30	27	31	34	26	31	24	8	234
	Lost to trace	0	3	2	4	4	3	4	0	2	0	1	1	0	0	24
	Deaths	0	3	15	6	11	22	26	27	29	34	25	30	24	8	230
	Person-years at risk	1,117	3,899	4,602	3,951	3,532	3,408	2,650	1,781	1,178	851	536	258	95	49	27,907
1926–30	Entries	227	267	48	13	9	2	0	3	1	0	1	0	0	0	571
	Exits	0	4	18	22	35	29	49	41	45	39	49	47	24	15	417
	Lost to trace	0	2	9	13	15	5	21	10	6	4	6	14	1	0	106
	Deaths	0	2	9	9	20	24	28	31	39	35	43	33	23	15	311
	Person-years at risk	544	2,842	4,624	4,719	3,945	3,436	3,244	2,481	1,618	989	655	365	144	65	29,671
1931–35	Entries	138	318	34	13	6	2	3	3	0	1	0	0	1	0	518
	Exits	0	3	8	21	18	51	62	63	65	69	55	39	21	25	510
	Lost to trace	0	0	0	4	3	6	11	8	3	2	6	1	1	0	45
	Deaths	0	3	8	17	15	45	51	55	62	67	49	38	30	25	465
	Person-years at risk	308	2,018	3,419	4,704	4,626	3,739	3,215	2,978	2,209	1,362	756	438	214	96	30,082
1936–40	Entries	160	409	51	8	6	3	2	2	3	0	0	0	0	0	644
	Exits	0	1	4	9	30	40	48	58	89	81	73	52	35	40	560
	Lost to trace	0	0	1	3	2	6	7	2	11	6	9	4	1	2	54
	Deaths	0	1	3	6	28	34	41	56	78	75	64	48	34	38	506
	Person-years at risk	289	1,993	2,609	3,524	4,620	4,469	3,476	2,896	2,614	1,856	1,040	522	259	140	30,307
1939–43	Entries	105	307	49	17	10	7	4	1	4	0	0	0	0	0	504
	Exits	0	3	1	9	23	40	41	59	65	87	103	53	48	34	566
	Lost to trace	0	0	0	5	3	4	3	5	5	6	6	6	3	2	48
	Deaths	0	3	1	4	20	36	38	54	60	81	97	47	45	32	518
	Person-years at risk	182	1,698	2,636	2,975	3,979	4,678	3,925	2,988	2,650	2,198	1,260	618	284	171	30,242

Table 17—Continued

Year	Category	Number by age														Total
		20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85+	
1949–53	Entries	49	452	258	44	13	9	7	5	1	2	1	0	0	0	841
	Exits	0	4	2	1	9	13	30	62	103	100	92	109	73	69	667
	Lost to trace	0	2	1	1	1	2	1	1	7	8	4	3	3	3	37
	Deaths	0	2	1	0	8	11	29	61	96	92	88	106	70	66	630
	Person-years at risk	171	2,520	3,992	3,571	3,070	2,972	3,734	4,151	3,174	2,282	1,750	1,234	564	282	33,467
1941–45	Entries	109	223	54	22	15	7	4	2	1	2	0	1	0	0	440
	Exits	0	3	3	8	17	30	46	66	58	69	101	72	43	38	554
	Lost to trace	0	0	0	2	2	8	3	4	3	2	6	4	1	1	36
	Deaths	0	3	3	6	15	22	43	62	55	67	95	68	42	37	518
	Person-years at risk	236	1,615	2,736	2,794	3,486	4,479	4,250	3,201	2,570	2,188	1,441	740	322	178	30,236
1946–50	Entries	186	725	285	55	19	11	10	3	0	1	1	0	0	0	1,296
	Exits	0	2	4	7	8	15	35	76	83	85	106	84	51	54	610
	Lost to trace	0	1	1	2	2	2	3	5	10	5	3	5	1	1	41
	Deaths	0	1	3	5	6	13	32	71	73	80	103	79	50	53	569
	Person-years at risk	331	2,184	2,991	3,094	2,858	3,430	4,312	3,928	2,839	2,194	1,731	1,041	485	246	31,664
1951–55	Entries	33	509	259	43	10	6	7	6	2	1	1	1	0	0	878
	Exits	0	3	7	5	4	14	20	55	100	109	83	115	96	90	701
	Lost to trace	0	2	2	1	0	0	3	1	7	6	6	3	4	4	39
	Deaths	0	1	5	4	4	14	17	54	93	103	77	112	92	86	662
	Person-years at risk	79	2,112	4,302	3,970	3,298	2,864	3,344	4,031	3,468	2,392	1,724	1,219	665	359	33,827
1956–60	Entries	53	632	220	41	16	11	9	4	2	0	1	0	0	0	989
	Exits	0	0	3	9	12	18	24	32	98	114	112	117	102	121	762
	Lost to trace	0	0	0	2	2	0	2	2	5	5	5	2	4	3	32
	Deaths	0	0	3	7	10	18	22	30	93	109	107	115	98	118	730
	Person-years at risk	82	1,952	3,754	4,942	4,119	3,278	2,805	3,141	3,596	2,914	1,870	1,212	714	441	34,820

entries to and exits from risk by 5-year periods. The total number of person-years at risk for any 5-year period ranges from 28,000 to 35,000. After 1930, each 5-year period had in excess of 30,000 person-years at risk. Table 18 shows by 5-year periods the person-years at risk contributed to the total by those dentists entering New England practice prior to 1921. The data in this table provide the basis for analysis of mortality of dentists entering practice before 1921.

Table 18. Persons-years at risk (contributed by dentists entering practice prior to 1921), 1921–60

Year	Number by age														Total
	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85+	
1921–25	420	2,916	4,366	3,862	3,502	3,382	2,634	1,776	1,175	851	532	260	98	44	25,818
1926–30	—	418	2,872	4,262	3,761	3,370	3,202	2,452	1,608	982	650	360	146	62	24,145
1931–35	—	—	410	2,822	4,135	3,542	3,138	2,930	2,182	1,351	748	432	208	96	21,994
1936–40	—	—	—	394	2,734	3,978	3,275	2,806	2,561	1,831	1,031	516	255	138	19,519
1941–45	—	—	—	—	373	2,618	3,761	3,004	2,471	2,132	1,419	734	319	176	17,007
1946–50	—	—	—	—	—	353	2,482	3,455	2,660	2,102	1,678	1,022	481	245	14,478
1951–55	—	—	—	—	—	—	330	2,274	3,036	2,240	1,650	1,174	654	356	11,714
1956–60	—	—	—	—	—	—	—	299	2,001	2,546	1,752	1,159	686	435	8,878

MISSING DATA

Although every practical attempt was made to follow up the survivorship status of each cohort member, 3 percent of the group were lost to trace. The distribution of dentists of uncertain survivorship is shown in table 19. During 1921–30, 129 dentists, or about 1 percent, were lost to trace. Of the entire group lost to trace, 286, or 78 percent, had practice entry dates prior to 1921. Of the 6,177 dentists entering practice in the period 1921–60, only 82, or 1 percent, have been lost to trace. Thus, the lost to trace group was an older group and their principal influence on the study is during 1921–30.

In analyses of mortality, two procedures may be followed in regard to subjects lost to trace. Only those known to be deceased may be counted in an analysis, on the assumption that none of those lost to trace are dead. On the other hand, those lost to trace may be assumed deceased and added to those known deceased. The two values obtained provide extremes of the range of the actual value. The above procedure was followed in analyzing results of this study relating to deaths from all causes. It was not followed in deaths due to specific causes because ranges so obtained would be too large for any practical value.

Table 19. Subjects lost to trace—their entry and exit dates and person-years at risk,[a] by age groups

Year and category		Number by age														Total
		20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85+	
Entries prior to 1921 [b]		0	0	17	47	44	57	36	34	18	10	21	1	1	0	286
1921–25	Entries	7	25	3	3	2	0	0	0	0	0	0	0	0	0	40
	Exits	0	3	2	4	4	2	4	0	2	1	1	1	0	0	24
	Person-years at risk	24	145	211	228	194	216	154	102	69	75	52	4	0	0	1,474
1926–30	Entries	2	8	4	0	1	1	0	0	0	0	0	0	0	0	16
	Exits	0	2	9	14	14	5	21	9	6	4	6	14	1	0	105
	Person-years at risk	9	76	142	181	201	162	172	126	88	52	48	31	1	0	1,289
1931–35	Entries	0	5	1	0	0	0	0	1	0	1	0	0	0	0	8
	Exits	0	0	0	4	3	6	11	8	3	2	6	1	1	0	45
	Person-years at risk	0	30	69	119	138	156	111	120	100	68	31	20	11	0	973
1936–40	Entries	0	5	0	0	1	0	0	0	0	0	0	0	0	0	6
	Exits	0	0	1	2	3	6	7	2	10	5	9	4	1	2	52
	Person-years at risk	0	14	36	64	98	115	119	76	86	79	41	16	14	8	766
1941–45	Entries	2	1	0	0	0	0	0	0	1	0	0	0	0	0	4
	Exits	0	0	0	2	2	8	3	4	3	2	6	4	1	1	36
	Person-years at risk	4	9	16	29	49	71	95	94	58	59	48	19	8	14	573
1946–50	Entries	1	2	2	0	0	0	0	0	0	0	0	0	0	0	5
	Exits	0	1	1	2	2	2	3	5	9	3	3	5	1	1	38
	Person-years at risk	3	11	12	10	18	31	50	70	65	48	39	26	11	15	409
1951–55	Entries	0	2	1	0	0	0	0	0	0	0	0	0	0	0	3
	Exits	0	2	2	1	0	0	3	1	6	6	6	3	3	4	37
	Person-years at risk	0	6	12	9	5	11	19	34	39	32	29	20	11	15	242
1956–60	Entries	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Exits	0	0	0	2	2	0	2	2	5	5	4	2	4	3	31
	Person-years at risk	0	0	2	4	4	2	5	6	12	12	9	8	6	6	76

[a] Person-years at risk listed for each group include those contributed by new entries, exits, and those remaining.
[b] Age distribution as of 1921.

The year of birth could not be definitely established for 288 cohort members, which is less than 3 percent of the total number. All except 16 of this group were subjects lost to trace; these 16 died after the end of the study. Rather than carry this group through the course of the study as of unknown age, each was assigned an estimated year of birth. This estimated year of birth facilitated the inclusion of each subject in an age distribution for the calculation of person-years at risk. Without this estimated year of birth, it would be difficult to calculate expected deaths from the standard age-specific rates applied throughout the study. Year of birth for each member of this group was estimated in the following manner. The year of entry into practice was known for each cohort member, ranging from 1883 to 1960. The average year of birth was calculated for each group of dentists entering practice each year from 1883 to 1960. From these data, an estimated year of birth was assigned (when missing), corresponding to the average year of birth of those dentists entering dental practice the same year. The distribution of this group by year, number, and person-years at risk contributed is shown in table 20. The majority of this group was lost to trace during the period 1921–30. From 1931 on, the person-years at risk contributed by these subjects were almost negligible.

Table 20. Distribution of subjects with estimated year of birth according to time lost to trace and their effect on person-years at risk [a]

Period lost to trace	N [b]	Person-years at risk [c]	Percent [d]
1921–25	100	892	3.2
1926–30	71	714	2.4
1931–35	33	462	1.5
1936–40	31	310	1.0
1941–45	12	210	0.7
1946–50	12	162	0.5
1951–55	7	125	0.4
1956–60	6	95	0.3
1921–60	272	2,970	1.2

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[a] Includes in person-years at risk computation, 16 subjects who died after completion of study.
[b] Number of subjects with estimated year of birth lost to trace.
[c] Number of person-years at risk contributed by cohort members with estimated year of birth.
[d] Person-years at risk from subjects with estimated year of birth expressed as a percent of total for a particular time interval.

MORTALITY FROM ALL CAUSES

COMPARISONS WITH THE GENERAL POPULATION

Observed deaths of cohort members were compared with those expected from death rates of the New England white male population. The results of this comparison are shown for 5-year periods in table 21. During the periods 1939–43 and 1949–53, expected deaths were calculated from New England specific death rates derived from or prepared by the National Office of Vital Statistics (*55, 56*). These were added to provide a check in adjacent time periods of rates prepared for this study.

In each time period, there were significantly fewer observed deaths than expected. Standardized mortality ratios range from 79 to 93 percent in the period 1931–60. These ratios were less than 70 in the 1920's and may be open to question. The number of cohort members untraced in the 1920's was discussed earlier. Without a doubt, some of these untraced should be in the deceased bracket, in which case numbers of deaths of dentists from 1921 to 1930 would be higher and the standardized mortality ratios in 1921–25 and 1926–30 more comparable to the trends observed in later years. All standardized mortality ratios from 1921 to

Table 21. Expected and observed deaths, all causes [a]

Year	Observed deaths	Expected deaths	Standard mortality ratio	Z
1921–25	260	378	69	7.3
1926–30	311	460	68	5.2
1931–35	465	523	89	2.7
1936–40	506	597	85	4.0
1939–43	518	641	81	5.4
1941–45	518	653	79	5.9
1946–50	569	704	81	5.7
1949–53	630	731	86	4.0
1951–55	662	763	87	3.9
1956–60	730	789	93	2.2
1921–60	4,021	4,867	83	13.3

[a] In this and subsequent tables of observed and expected deaths, the numbers of expected deaths have been rounded off for convenience. Standardized mortality ratios were calculated before rounding, and in some instances do not agree with that value obtained from the use of the rounded expected numbers given in the tables.

1955 are significantly different from 100 percent at the 1 percent level.[2] The standardized mortality ratio for 1956–60 is significant at the 3 percent level.

One method of managing cohort members lost to trace is to assume that they are deceased. Analyses have been repeated with lost members assumed to have died during the time period in which they were lost to trace. Standardized mortality ratios have been calculated and tested for significance. The results are shown in table 22. During the 1921–30 period of this study there was a concentration of subjects of unknown survivorship. The upper limit of the actual values of standardized mortality ratios is shown in table 22. Even in this extreme situation, mortality ratios remain significantly low in all 5-year periods except 1931–35 and 1956–60.

The standardized mortality ratios in tables 21–22 suggest that mortality in recent years has been advancing to the level of the general population. However, these ratios have been approaching unity because of the design of the study. Age distributions have shifted since exits have been permitted only due to death or "lost to trace." The effect of increasing numbers of older members may be reduced by limiting analysis to those members under a certain age level.

Table 22. Standard mortality ratios based upon dead and lost assumed dead, combined

Year	Standard mortality ratio	Z
1921–25	75	5.6
1926–30	91	2.0
1931–35	98	0.6
1936–40	94	1.6
1941–45	85	4.2
1946–50	86	3.9
1951–55	92	2.3
1956–60	97	1.0

The analyses shown in tables 21–22 have been repeated for the age group 25–69 and are shown in table 23. No deaths have occurred among dentists in the 20–24-age bracket. Inclusion of this age group would only decrease further the mortality ratios shown in table 23. By excluding the oldest age groups, a more consistent pattern of mortality is evident. This consistency is present in analyses with and without cohort members of uncertain survivorship. Previous comparisons have shown highest mortality in the 1930's. This is still apparent in the age group 25–69. The highest mortality ratios obtained, with and without lost members, are seen in the period 1931–35. During this 5-year period, observed deaths were not significantly different from those expected if dentists were subject to the death rates of the general population. Mortality appears to have increased up to 1935 and then decreased, in analyses of known deceased, and of known deceased plus untraced presumed deceased.

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[2] Throughout the text, standardized mortality ratios are described as statistically significant, when in fact the significance relates to the difference between the observed ratio and 100 percent.

All standardized mortality ratios calculated from known deaths in the age group 25–69 are highly significant. All ratios in the same age group calculated with lost members assumed dead are also significant, except during the 1930's. During the 40-year period encompassed by this study, the mortality of New England dentists age 25–69 was between 75 and 85 percent of the general population. This observed difference is highly significant.

Table 23. Deaths observed and expected from all causes from age 25 to 69 inclusive

Year	Observed[a]	Observed[b]	Expected	S.M.R.[a]	Z[a]	S.M.R.[b]	Z[b]
1921–25	173	195	278	62	8.0	70	5.9
1926–30	197	282	326	60	9.2	87	2.6
1931–35	323	360	363	89	2.2	99	0.2
1936–40	322	360	391	82	3.8	92	1.6
1941–45	276	300	391	71	6.9	77	5.3
1946–50	284	315	374	76	5.3	84	3.3
1951–55	295	317	377	78	4.8	84	3.4
1956–60	292	310	379	77	5.1	82	3.9
1921–60	2,162	2,439	2,879	75	15.4	85	8.9

[a] Observed deaths.
[b] Observed deaths plus those lost to trace.

COMPARISONS WITH U.S. PHYSICIANS

Mortality in the cohort has been compared with that of physicians. However, this comparison introduces a geographic variable since available death rates for physicians are applicable to the entire United States. Table 24 shows a comparison of observed deaths during 1921–30 and those expected from rates published by Emerson and Hughes for U.S. physicians in 1925 (*57*). The standardized mortality ratio for known deaths is 73 percent, and for known deaths combined with those lost to trace is 90 percent. Both of these ratios are highly significant.

Death rates for U.S. physicians during 1938–42, calculated by Dublin and Spiegelman (*58*), were utilized to predict cohort deaths for the period 1939–43. As shown in table 25, known deaths result in a standardized mortality ratio of 86 percent, which is highly significant. When known deaths are combined with those lost to trace during this period, the ratio is 94 percent and only approaches statistical significance.

Physician mortality comparisons during 1949–53 were made with expected deaths calculated from rates prepared by Dickinson and Martin (*59*). The results are shown in table 26. Standardized mortality ratios are 93 percent for known deaths and 98 percent for the latter combined

Table 24. Comparison of observed deaths and those expected from 1925 death rates of U.S. physicians [a]

Deaths	Number by age			Total
	25–44	45–64	65+	
Observed [b]	75	226	270	571
Observed [c]	128	277	297	702
Expected deaths	159	327	294	780

[a] Numbers of expected deaths are the products of 1925 physician rates and dentist-years at risk 1921–30.

[b] Refers to known deaths.

[c] Refers to a combination of known dead plus lost to trace assumed dead for this comparison.

Table 25. Comparison of observed deaths and those expected from 1938 to 1942 death rates of U.S. physicians [a]

Deaths	Number by age						Total
	25–34	35–44	45–54	55–64	65–74	75+	
Observed [b]	4	24	74	114	178	124	518
Observed [c]	4	32	81	124	190	135	566
Expected	8	28	93	152	183	139	603

[a] Number of expected deaths are the products of 1938–42 physician rates and dentist-years at risk from 1939 to 1943.

[b] Refers to known deaths.

[c] Refers to known deaths plus those lost to trace assumed dead for this comparison.

with those lost to trace. Dickinson and Martin concluded that physician mortality had remained unchanged from 1925 to 1951 in relation to that of the U.S. white male population. However, the summary data in table 27 suggest that mortality of cohort members changed during this same time period in relation to physician mortality. This assumption is valid only if the age distributions are similar. During 1925, New England dentists were more concentrated in the younger age groups than physicians. By 1950, the median age of U.S. physicians was in the 35–44-year-age bracket, while New England dentists' median age was in the 45–54-year-age bracket.

Table 26. Comparison of observed deaths and those expected from 1949 to 1951 death rates of U.S. physicians [a]

Deaths	Number by age						Total
	25–34	35–44	45–54	55–64	65–74	75+	
Observed [b]	3	8	40	157	180	242	630
Observed [c]	6	10	43	165	192	251	667
Expected	9	20	64	164	199	225	681

[a] Numbers of expected deaths are the products of physician rates and cohort person-years at risk, 1949–53.
[b] Refers to known deaths.
[c] Refers to known deaths plus those lost to trace.

Table 27. Summary of comparisons of dentist and physician mortality

Year	S.M.R.[a]	Z[a]	S.M.R.[b]	Z[b]
1921–30	73	8.8	90	2.9
1939–43	86	3.7	94	1.6
1949–53	93	2.0	98	0.5

[a] Standard mortality ratios based on known deaths.
[b] Standard mortality ratios based on known deaths, plus lost to trace assumed dead.

The effect of different age distributions has been remedied in part by repeating the above analyses separately for ages under 65 and those 65 and over, as shown in table 28. In the 25–64-age group, cohort members show a favorable, although diminishing, mortality differential in relation to U.S. physicians. The standardized mortality ratios shown are statistically significant under age 65, even when those members lost to trace are also assumed dead. However, above age 64, all ratios are close to 100 percent and are not statistically significant.

This difference between the mortality of physicians and dentists may also be demonstrated in death rates of physicians published by the National Vital Statistics Division of the U.S. Public Health Service (*60*). Age specific rates from this source were used to compute expected deaths from 1946 to 1955 cohort person-years at risk. Observed and expected deaths from all causes are shown in table 29. The actual value of the mortality ratio rests between 73 and 81 percent, the extreme range of the ratios for known dead and known dead plus those lost to trace assumed dead. Standardized mortality ratios computed around 1950 show slight variation using the rates of Dickinson and Martin (*59*), and the U.S. Public Health Service (*60*). The latter death rates are higher, but are based on a more adequate source of information concerning deaths of physicians.

Table 28. Summary of comparisons of dentist and physician mortality, by age

Category and year	Age 25—64				Age 65+			
	Observed	Expected	S.M.R.	Z	Observed	Expected	S.M.R.	Z
Known deaths only:								
1925	301	486	62	10.7	270	294	92	1.5
1938-42	216	281	77	4.4	302	322	94	1.2
1949-51	208	257	81	3.4	422	424	100	0.1
Known deaths plus those lost to trace:								
1925	405	486	83	4.0	297	294	101	0.2
1938-42	241	281	86	2.6	325	322	101	0.2
1949-51	224	257	87	2.2	443	424	104	0.9

Table 29. Observed deaths from all causes, age 20–64, 1946–55, and those expected from 1950 U.S. physician rates

Category	Observed	Expected	S.M.R.	Z
Known deaths	396	539	73	7.2
Known deaths plus those lost to trace	438	539	81	4.8

In a study of mortality of radiologists, Seltser and Sartwell (*63*, *64*) calculated age-specific death rates from 1935 to 1961 for three physician specialty groups—radiologists, internists, and ophthalmologists—combined with otolaryngologists. Numbers of deaths expected from these rates and those observed are shown by age, time, and specialty in table 30. During 1936–45 and 1946–55, the mortality of dentists was about that of internists, and significantly less than that of radiologists, and greater than that of ophthalmologists and otolaryngologists. However, during 1956–60, dentist mortality was greater than expected from rates of all specialists, including the radiologists.

This change is shown better in the form of standardized death rates for the three specialty groups and cohort members. Rates were standardized on the age 35–79 distribution of all physicians in 1950 (*59*), and are shown in table 31 and figure 3. Obviously, death rates for cohort members have remained about the same, while the rates for all physician specialty groups have decreased.

The different results obtained through the use of various physician and physician specialty mortality rates are not so contradictory as they may seem at first. Dublin and Spiegelman (*72*), have shown that certain medical specialists have had more favorable mortality experience than general practitioners.

Table 30. Comparison of observed deaths from all causes and those expected from death rates of medical specialists, age 35–79, 1936–60 [a]

Year	Category		Number by age									
			35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	Total	S.M.R.
1936–45	Observed	Cohort	12	42	56	84	117	133	142	158	116	860	—
	Expected	RSNA [b]	22	50	76	103	124	147	175	161	119	977	88
	Expected	ACP [c]	15	32	59	59	111	140	157	134	118	825	104
	Expected	AAOO [d]	19	11	44	71	110	149	104	84	90	682	126
1946–55	Observed	Cohort	9	10	27	49	125	166	183	180	191	940	—
	Expected	RSNA [b]	8	15	36	80	148	182	218	239	162	1,088	86
	Expected	ACP [c]	13	17	38	63	128	153	170	157	173	912	103
	Expected	AAOO [d]	8	18	33	48	114	136	116	174	143	790	119
1956–60	Observed	Cohort	7	10	18	22	30	93	109	107	115	511	—
	Expected	RSNA [b]	3	9	8	17	43	72	101	122	96	471	108
	Expected	ACP [c]	—	8	14	15	35	61	93	84	100	410	125
	Expected	AAOO [d]	6	7	10	13	35	72	86	85	75	389	131

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[a] References *63*, *64*.
[b] RSNA, Radiological Society of North America.
[c] ACP, American College of Physicians.
[d] AAOO, American Academy of Ophthalmologists and Otolaryngologists.

Table 31. Age adjusted death rates per 1,000 for physician specialities and cohort members, age 35–79 [a]

Specialist	Rate by year		
	1936–45	1946–55	1956–60
Cohort members	18.88	16.28	16.78
Radiologists	21.14	18.77	15.43
Ophthalmologists and Otolaryngologists	14.45	13.83	12.64
Internists	18.13	15.84	13.51

[a] Adjusted on the age distribution of all U.S. white male physicians in 1950.

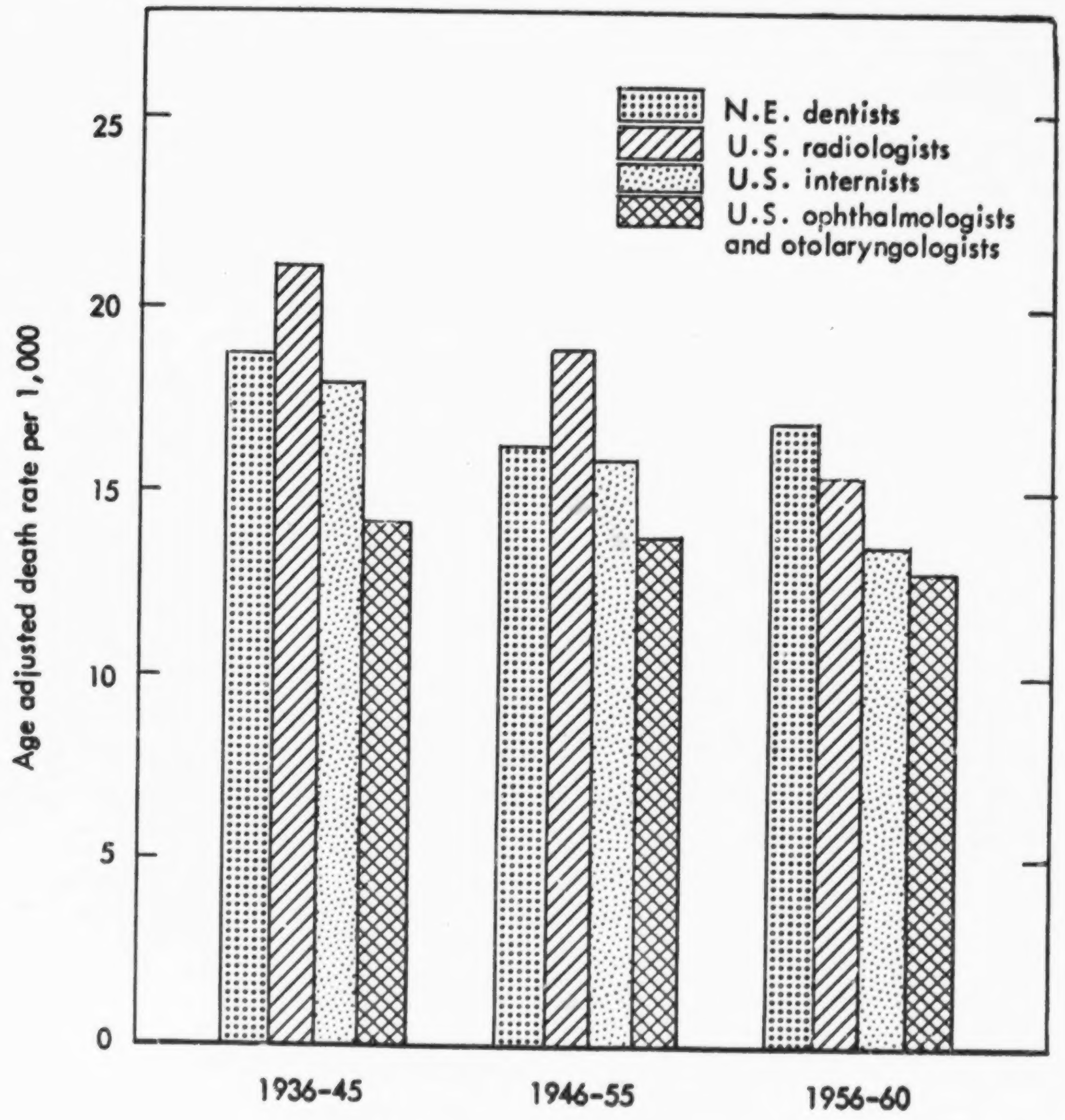

Figure 3. Age adjusted death rates per 1,000 for selected specialists 1936–60 (using the 1950 age distribution of all U.S. physicians)

COMPARISONS WITH U.S. DENTISTS

In a study of mortality by occupation, the National Vital Statistics Division of the U.S. Public Health Service has recently published age-specific death rates for all causes for U.S. dentists (*60*). These rates were based upon the findings of the 1950 U.S. Census and deaths of all dentists, age 20–64, occurring in 1950. Since the rates were effective for 1950, they were used to calculate expected deaths from the cohort person-years at risk for the period 1946–55. The results of this comparison are shown in table 32. In this table, expected deaths are again compared with known deaths, as well as known deaths plus those lost to trace. Under age 35 there are few deaths and no significant findings. From age 35 to 59, however, observed deaths from either method always are less than expected, and the differences are statistically significant. This is not true in the age group 60–64, where observed deaths exceed those expected.

For all ages combined, New England dentists show an extremely favorable standardized mortality ratio, within the range of 78 to 86 percent and highly significant. Obviously, it is because of the favorable mortality experience of New England dentists under age 60.

Table 32. Deaths observed in the cohort 1946–55, and those expected from 1950 rates of all U.S. white male dentists

Deaths	Number by age							Total
	20–24	25–29	30–34	35–44	45–54	55–59	60–64	
Observed [a]	—	2	8	19	76	125	166	396
Observed [b]	—	5	11	24	84	131	183	438
Expected	1	4	7	39	140	161	155	507
S.M.R. [a]	—	50	114	49	54	78	107	78
Z [a]	—	1.4	0.4	4.6	7.3	3.1	0.8	5.6
S.M.R. [b]	—	125	157	62	60	81	118	86
Z [b]	—	0.4	1.2	3.1	6.1	2.5	2.1	3.3

[a] Known deaths.
[b] Known deaths plus lost to trace assumed dead.

MORTALITY FROM LEUKEMIA

COMPARISONS WITH NEW ENGLAND AND U.S. MALES

The distribution of observed and expected deaths from leukemia is shown in table 33. Deaths expected from New England population

Table 33. Observed deaths from leukemia and those expected from New England standards

Year	Observed	Expected	S.M.R.	Z
1921–25	—	1	—	—
1926–30	2	1	200	0.7
1931–35	2	1	200	0.7
1936–40	2	2	100	—
1941–45	2	2	100	—
1946–50	3	4	75	0.6
1949–53	7	4	175	1.1
1951–55	7	4	175	1.1
1956–60	3	6	50	1.7
1921–60	21	21	100	—

rates during 1921–60 numbered 21, the same number observed. No significant surplus leukemia mortality was observed during any 5-year period.

Expected deaths have also been calculated utilizing U.S. leukemia rates prepared by Gilliam and Walter (*73*). In these computations, the rates for 1951–55 were also used to predict deaths expected during 1956–60. Deaths expected from this standard, shown in table 34 numbered 19, or 2 less than the value derived from the rates prepared for New England. Studies of geographic variation in leukemia incidence have shown that the New England incidence approximated the national average, at least in recent years (*74*).

The distribution by type of leukemia observed was as follows:

Chronicity	Cell type	Number
Acute	Lymphatic	2
	Unknown	3
Chronic	Myeloid	8
	Lymphatic	1
Unknown	Myeloid	1
	Lymphatic	2
	Monocytic	3
	Unknown	1

The numbers of deaths by cell type are too small for statistical evaluation. However, it is noteworthy that the ratio of chronic myeloid to lymphatic cases is 8 to 1.

Table 34. Observed deaths from leukemia and those expected from U.S. standards

Year	Observed	Expected
1921–25	0	1
1926–30	2	1
1931–35	2	1
1936–40	2	2
1941–45	2	2
1946–50	3	3
1951–55	7	4
1956–60	3	5[a]
1921–60	21	19

[a] 1951–55 rates used to calculate numbers of expected deaths. An extra death has been added to this period to account for rounding during 1951–60 that would produce a discrepancy in the 1921–60 total.

COHORT ANALYSIS

Those dentists who entered practice prior to 1921 have been evaluated separately, on the assumption that dentists educated earlier had less appreciation of the hazards of exposure to X-radiation. Person-years at risk for 1921–60 were computed for that group entering practice prior to 1921, and expected leukemia deaths calculated, utilizing New England and U.S. standard rates.

The leukemia deaths observed are shown in table 35, in order of year of entry to practice, along with years of birth and death. The identification number used merely identifies these deaths in a sequence based upon year of entry to practice. Out of the total of 21 leukemia deaths observed, 15 occurred in the group of early entries. Depending upon the use of U.S. or New England standard rates, 14 or 16 leukemia deaths, respectively, were expected. Observed deaths numbered 15, just between the above expected values. Obviously, early entry to practice conferred no increase in leukemia mortality.

EFFECT OF UNTRACED SUBJECTS

No mention has been made of the possible effect of those cohort members whose survivorship was uncertain. A total of 368 dentists was lost to trace and contributed 5,802 person-years at risk. This last group may differ markedly from the others in many respects. However, the probability of the lost to trace group producing sufficient leukemia deaths to alter the findings significantly is extremely remote ($p < 0.00001$).

Table 35. Distribution of observed leukemia deaths according to year of entry to risk

Sequence number	Year of		
	Birth	Entry	Death
1	58	94	30
2	77	99	54
3	79	02	60
4	80	02	49
5	75	04	44
6	86	07	54
7	87	08	47
8	80	09	50
9	82	10	52
10	89	10	38
11	75	12	26
12	93	15	52
13	93	18	51
14	89	19	58
15	91	19	45
16	01	22	38
17	91	23	33
18	96	24	33
19	00	24	51
20	90	27	52
21	20	43	57

RELATION OF FINDINGS TO X-RAY EXPOSURE

Thus, observed leukemia mortality has generally equaled that expected from several series of standard rates. If available evidence of past radiation exposure were representative of all dentists, surplus leukemia would be expected. Several factors must be considered in relation to the negative findings. The likelihood is extremely remote that the untraced group might produce enough leukemia cases to alter the results. Another possible source of error in mortality studies is the level of medical care available to the cohort. According to most standards, dentists have been classified in the upper socio-economic bracket. If medical care were an important factor, it would be expected to operate on the positive rather than the negative side of leukemia case findings.

Another factor to be considered is precision of diagnosis. Both aplastic anemia and multiple myeloma have been considered as entities that might, on occasion, be confused clinically with leukemia (*10*). However, in this study only one death each due to aplastic anemia and multiple myeloma occurred. The assignment of these deaths to leukemia would not change the conclusions. The possibility of leukemia as a cause of death and erroneously assigned to some other cause must be acknowledged. However, this is less likely in a group of high socioeconomic status. The likelihood of this error is far greater in the general population used as the standard.

In a consideration of radiation-induced leukemia, a basic factor is the amount of radiation exposure and its intensity. As discussed previously, only estimates of radiation exposure are available for large numbers of dentists. These must be used with caution, since they are not based on the entire dentist population or even on a random sample.[3] Three reports provide information concerning radiation exposure of dentists during the last 10 years of this study. One film badge survey estimated the mean weekly dose of dentists to be 0.2 roentgen; a second found that 10 to 20 percent were exposed to more than 0.2 roentgen per week in 1958. Another report estimated that in 1958, 13 percent were exposed to more than 0.1 roentgen per week. Obviously, those dentists without or not using X-ray equipment would be omitted from such surveys. This would tend to inflate estimates of exposure.

The operating voltage of dental X-ray machines until recent years has been largely in the range of 45 to 65 kilovolts. Furthermore, the dentist has used X-radiation in radiography rather than fluoroscopy. Unless a dentist has held films for patients during exposure or stood in the primary beam, the principal source of exposure was secondary radiation. Secondary radiation is of less intensity than that of the primary beam, and is partially absorbed in soft tissue before reaching the bone marrow. This exposure to secondary radiation may be comparable to the situation reported by Murray *et al.* (*13*). Children exposed to deep X-ray treatment showed surplus mortality from leukemia, while those exposed to superficial X-ray treatment of skin lesions showed no increase in leukemia risk. In the case of exposure of dentists to X-radiation, the combination of low intensity primary radiation and partial absorption of secondary radiation may have reduced effective leukemogenic radiation to extremely low levels.

The failure to demonstrate an increased risk of leukemia may be due to one of the following:

1. No increased risk existed.
2. The sample size was too small to detect a small increase in risk.
3. Exposure to X-radiation reached a peak during 1950–60 and its effect is yet to be demonstrated.

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[3] Extensive radiological monitoring of dental X-ray machines is now carried out in Massachusetts by the State Health Department, pursuant to regulatory legislation passed in 1962. Film badges have since been provided to dentists. Few badges have registered exposure in excess of 0.1 roentgen per week according to the Massachusetts State Health Department.

Unfortunately, this study of dentists, like those of radiologists, adds little to the dose-response relation of leukemia and ionizing radiation. However, the study has shown that leukemia mortality among the dentists studied did not constitute a demonstrable occupational risk to date.

MORTALITY FROM CANCER

COMPARISONS WITH NEW ENGLAND MALES

The distribution of deaths from all forms of cancer is shown in table 36. Expected deaths have been calculated from death rates for New England white males. From 1921 to 1960, only 75 percent of those cancer deaths expected were observed. Deficiencies of cancer deaths were significant except for the periods 1921–25 and 1949–55. From 1926 on, there appears a tendency for cancer mortality to increase gradually. However, it must be remembered that the design of the study favors an age distribution increasing at the upper end.

The effect of the upper, open-end age group has been removed by studying observed and expected cancer deaths in those dentists under age 70. The results of this analysis are shown in table 37. Standardized mortality ratios are changed only slightly, except for the 1921–25 period. Elim-

Table 36. Observed and expected cancer deaths

Year	Observed	Expected	S.M.R.	Z
1921–25	34	39	87	0.9
1926–30	28	52	54	4.5
1931–35	46	73	63	4.0
1936–40	56	77	73	2.8
1939–43	63	87	72	3.0
1941–45	62	92	67	3.8
1946–50	72	113	64	4.8
1949–53	106	120	88	1.4
1951–55	121	131	92	0.9
1956–60	119	140	85	1.9
1921–60	538	717	75	7.7

Table 37. **Observed and expected cancer deaths, age 20–69**

Year	Observed	Expected	S.M.R.	Z
1921–25	21	29	72	1.7
1926–30	20	38	53	4.0
1931–35	37	53	70	2.6
1936–40	36	52	69	2.6
1941–45	43	58	74	2.2
1946–50	46	64	72	2.6
1951–55	62	72	86	1.2
1956–60	57	76	75	2.5
1921–60	322	442	73	6.6

inating the oldest age group reduced the ratio from 87 to 72 percent, but failed to make the ratio statistically significant. However, during 1956–60, the ratio was reduced from 85 to 75 percent, the latter also associated with a lower probability. The years 1951–55 remain the only recent period during which the observed cancer deficiency was not statistically significant.

COHORT ANALYSIS

Again it has seemed worthwhile to evaluate separately the mortality of those dentists entering risk prior to 1921. Person-years at risk for cohort members entering practice prior to 1921 and later were computed separately to permit the comparisons of the mortality of the two groups. Table 38 shows observed and expected cancer deaths for these two groups. Cancer mortality ratios for the entire group, table 36, are generally similar to those of the cohort of early entries, table 38. During the last 10 years, analyses of all study members showed ratios less than 100 percent but were not statistically significant. Similar ratios hold for analyses of early entries during 1951–60, while later entries during the same period showed ratios less than unity and were statistically significant. Obviously, there were great age differences between the two groups, working in favor of increased cancer mortality in the cohort of early entries. However, the overall cancer deficit was evident, regardless of date of entry to risk.

Table 38. Observed and expected cancer deaths according to year of entry to practice

Year	Entry before 1921				Entry after 1920			
	Observed	Expected	S.M.R.	Z	Observed	Expected	S.M.R.	Z
1921–25	34	38	89	0.7	0	1	—	—
1926–30	27	50	54	4.4	1	2	50	1.0
1931–35	43	70	61	4.1	3	3	100	—
1936–40	50	73	68	3.3	6	4	150	0.8
1941–45	59	84	70	3.3	3	8	38	2.9
1946–50	60	98	61	4.9	12	15	80	0.9
1951–55	104	103	101	0.1	17	28	61	2.7
1956–60	88	97	91	1.0	31	43	72	2.2
1921–60	465	613	76	6.9	73	104	70	3.6

The difference between the standardized mortality ratios of early and late entries has been tested for statistical significance in the following formula:

$$Z=\frac{\text{S.M.R.}_e-\text{S.M.R.}_l}{\sqrt{\frac{(\text{S.M.R.}_e)^2}{\text{Observed}_e}+\frac{(\text{S.M.R.}_l)^2}{\text{Observed}_l}}}.$$

The subscripts e and l refer to the values for the groups of early and late entry dates. Substituting the appropriate figures from table 38 into this formula, a Z ratio is obtained with an associated probability of 0.4, demonstrating no significant difference between the two standardized mortality ratios. Obviously, those entering practice prior to 1921 were subject to about the same cancer mortality as those dentists entering later.

An inverse relation between cancer mortality and social class has been reported by the Registrar-General of England and Wales. Table 39 shows mortality ratios for all cancer deaths according to the five British social classes (*69*). A wide and consistent gradient was evident in early years. By 1953, the gradient had decreased in size and consistency. This decreased differential between standard and observed deaths is evident in this study, except for the high (87 percent) ratio observed for 1921–25. Similarity is also found in a comparison of British and New England dentists under age 65, who demonstrated cancer mortality ratios of 83 and 81 percent, respectively, during 1949–53. New England and

British dentists have experienced cancer mortality approximating or somewhat less than that expected in a group of high socio-economic status.

Table 39. Standardized mortality ratios for male cancer deaths (age 20–64) by social class in England and Wales [a]

Year	Social class				
	I	II	III	IV	V
1921–23	80	92	99	97	123
1930–32	83	92	99	102	115
1949–53	94	86	104	95	113

[a] Reference *69*.

COMPARISONS WITH U.S. PHYSICIANS

The cancer mortality of dentists in this study has been compared with that of U.S. physicians. Comparison data are available for 1925, 1938–42, and 1949–51 (*57–59*). For the last two time periods, total numbers of cancer deaths were presented, but no rates. Therefore, comparisons were made by computing cancer deaths expected among physicians if they were subject to the rates of dentists. Age-specific rates for dentists were formulated using numbers of known cancer deaths and the appropriate age-distributed person-years at risk. The format of physician comparisons varies from previous analyses in that expected deaths are based on standards derived from dentists, and observed deaths are those of the comparison group. Rates used to predict expected physician deaths were specific for 10-year-age brackets: for example, 25–34, 35–44, and so forth. However, the results shown in table 40 are limited to three broader-age categories.

Table 40 shows a great discrepancy in observed and expected cancer deaths. The standardized mortality ratio of 54 percent has a Z value of 9.2, indicating a high statistical significance. This is due to a surplus, relative to physicians, of cancer deaths in the older group of dentists. The difference observed may be an artifact owing to the use of 1925 physician rates and 1921–30 dentist-years at risk. During 1921–30, cohort members over age 69 experienced deaths due to cancer about equal to that expected from general population rates. Therefore, the cancer rates, used to compute expected deaths in the upper age brackets of physicians, are about the same as general population rates. In 1925, the cancer death rate of physicians was only 55 percent of that of the general male population over age 25.

Table 40. Cancer deaths observed in U.S. physicians, 1925, and those expected from 1921 to 1930 cohort rates

Age	Deaths		S.M.R.
	Observed	Expected	
25–44	7	12	58
45–64	72	77	94
65+	38	127	30
Total	117	216	54

The 1925 age distributions of cohort members and all U.S. physicians are shown in table 41. At this date, the New England dentists, as a group, were younger than U.S. physicians. If age alone were to affect comparisons of cancer mortality, the opposite of the difference observed would be expected.

For the period 1938–42, cohort cancer rates were formulated for 10-year-age brackets; for the period 1949–51, age groups were of 5-year intervals. The different age groupings were necessitated by differences in the detail available for physicians' age distributions. Table 42 shows observed physician cancer deaths for 1938–42 and 1949–51, and those deaths expected if physicians were subject to the same cancer death rates as New England dentists. In each time period, physician cancer deaths have been about 93 percent of those expected from the cancer experience of New England dentists. In the three studies of physician mortality cited above, cancer deaths were less than those expected from general population rates. In other words, physician mortality due to cancer has been less than that expected from rates of the general population as well as dentists. Except for the unusual findings in the 1920's, observed

Table 41. Percentage age distribution of U.S. physicians and New England dentists, 1925

Category	Percentage by age						Total
	<35	35–44	45–54	55–64	65–74	75+	
U.S. physicians [a]	15	24	31	18	9	3	100
New England dentists	32	27	22	12	5	2	100

[a] Reference 57.

differences between physicians and dentists are not statistically significant. When the 1925 analysis of deaths is limited to age 25–64, a standardized mortality ratio of 89 percent is obtained, approximating the 92 and 93 percent values for all ages in later comparisons. No explanation is apparent for this differential in cancer mortality between physicians and dentists over age 65 during 1921–30.

Age distributions of U.S. physicians and New England dentists are shown in table 43 for 1940 and 1950. The median age of dentists is greater than physicians in each year. This age differential may contribute to the observed discrepancy in cancer mortality. In any event, dentists, like physicians, have experienced significantly less cancer mortality than the general population. Differences observed between dentists and physicians are not statistically significant (1940 and 1950).

Table 42. Cancer deaths observed in U.S. physicians and those expected from rates of cohort members, 1938–42 and 1949–51

Year	Observed[a]	Expected[a]	S.M.R.	Z
1938–42	332	362	92	1.6
1949–51	510	546	93	1.6

[a] Annual average number of cancer deaths.

Table 43. Age distributions, U.S. physicians and cohort members, 1940–50[a]

Year	Category	Percentage by age								Total
		<25	25–34	35–44	45–54	55–64	65–74	75–84	85+	
1940	U.S. physicians	0.6	23.8	22.8	17.9	18.0	12.6	3.7	0.6	100
	New England dentists	0.7	16.2	23.6	27.7	17.8	10.8	2.7	0.5	100
1950	U.S. physicians	1.3	23.4	26.7	18.7	13.5	10.7	5.0	0.7	100
	New England dentists	0.5	19.9	18.9	21.0	21.8	11.9	5.2	0.8	100

[a] References *58, 59*.

MORTALITY FROM CANCER OF SPECIFIC SITES

BUCCAL CANCER

Mortality from buccal cancer has constituted only 5 percent of all cancer deaths and would not be noteworthy were it not in the dentists' own specialty area, at least anatomically. During the entire study period, buccal cancer mortality was 66 percent of that expected from New England population rates, as shown in table 44. However, this scarcity of buccal cancer deaths was most pronounced in the period 1921–40. From 1941 to 1960, the observed deficiencies were not statistically significant.

During the period 1921–40, observed and expected deaths from buccal cancer numbered 5 and 16, producing a highly significant standardized mortality ratio of 31 percent. During 1941–60, with 20 observed and 22 expected deaths, the pattern was markedly different. Over the years encompassed by this study, buccal cancer mortality in the general population has declined steadily. Analysis of the decrease by age reveals the greatest decline in rates during middle adult ages. Since 1941, marked reductions in the death rates for the age group 65–74 were evident in the general population. However, during the last 15 years of the study period, mortality from buccal cancer exceeded that expected in those age groups under age 70, although the surplus was not statistically significant.

In England and Wales, buccal cancer has shown an inverse relation to socio-economic status (*69*). The U.S. 1950 occupational mortality

Table 44. Observed and expected deaths from buccal cancer

Year	Observed	Expected	S.M.R.	Z
1921–25	1	3	33	2.0
1926–30	1	3	33	2.0
1931–35	2	5	40	2.1
1936–40	1	5	20	4.0
1941–45	4	5	80	0.5
1946–50	4	6	67	1.0
1949–53	4	5	80	0.5
1951–55	4	5	80	0.5
1956–60	8	6	133	0.7
1921–60	25	38	66	2.6

survey demonstrated a mortality ratio of 75 percent for buccal cancer in all professional workers. These observations in the United States and Britain would lead one to expect less buccal cancer in dentists.

The buccal cancer mortality observed in dentists has not been solely due to the aging of the group and associated higher rates. During the last 20 years of the study, those study members under age 70 experienced 100 percent of expected mortality.

In a 1947 study of the U.S. general population, 64 percent of buccal cancer cases were diagnosed as localized to the site of origin (*75*). The data from this study suggest that the situation has been different for dentists.

These results certainly fail to demonstrate that dentists have experienced less mortality from buccal cancer than the general population, in spite of dentists' socio-economic status and special training, both of which should work in favor of decreased mortality.

CANCER OF THE PANCREAS

A surplus of deaths from cancer of the pancreas in British radiologists has been reported (*8*). Mortality from this cancer among cohort members was compared with that of the general U.S. white male population. Deaths from cancer of the pancreas for all U.S. white males in 1950 were divided by the number of U.S. white males, according to the census of the same year, to obtain age-specific rates for 5-year-age groups 20-24 and above. Products of the above rates and appropriate person-years at risk were accumulated to obtain the number of expected deaths due to cancer of the pancreas. A total of 23 deaths due to cancer of the pancreas was tabulated: 5 during 1921–40, and 18 during 1941–60. All except two of these deaths occurred in dentists entering practice prior to 1921. The person-years at risk of cohort members entering practice prior to 1921 were used to determine the expected number of deaths. During the period 1941–60, a total of 17 deaths from cancer of the pancreas was expected in that group of dentists which entered practice prior to 1921. Expected deaths numbered 16. As in the case of leukemia, no surplus was evident.

CANCER OF THE RESPIRATORY SYSTEM

Mortality from all forms of cancer has been significantly less than expected. However, this was not true of cancer of the respiratory system. These observed and expected deaths are shown in table 45. Information is available only from 1931, since prior to the Fourth International Revision respiratory cancer was not listed under a separate rubric.

Only during 1941–45 was there a statistically significant deficiency of deaths from cancer of the respiratory system. The 83 percent standardized mortality ratio for the 30-year period only approaches statistical

Table 45. Observed and expected deaths from cancer of the respiratory system

Year	Observed	Expected	S.M.R.	Z
1931–35	4	5	80	0.5
1936–40	4	7	57	1.5
1941–45	6	11	55	2.0
1946–50	13	17	76	1.1
1949–53	21	18	117	0.7
1951–55	27	23	117	0.8
1956–60	23	30	77	1.5
1931–60	77	93	83	1.8

significance. This is largely due to the paucity of deaths observed during the first half of this period. During the last 15 years, when mortality from lung cancer (specifically) had greatly increased in the general population, 63 deaths were observed with 70 expected. The difference between these values is not significant. During the period 1949–53, British dentists also showed respiratory cancer mortality close to that of the general population (*69*).

Mortality from lung cancer, specifically, has been studied using as standards rates prepared by Gilliam *et al.*, applicable to all U.S. white males (*76*). These age-specific rates were for 2- and 3-year periods from 1930 to 1958. In order to utilize an average rate close to the midpoint of the periods for which age-distributed person-years at risk were computed for the cohort, values halfway between successive published rates were taken to predict expected deaths. To compute expected deaths for the periods 1941–45 and 1956–60, rates for 1942–44 and 1957–58 were used, respectively. Lung cancer here is actually cancer of the respiratory system, exclusive of the larynx. This grouping of titles was recommended in order to secure the greatest degree of comparability of cancer classification in successive revisions of the International List of Causes of Death.

The number of lung cancer deaths observed and those expected from the above rates are shown in table 46. The overall result is similar to that for cancer of the respiratory system. However, the discrepancy between observed and expected deaths is less. Observed deaths for the 30-year period are 93 percent of those expected. During the last 15 years, 56 lung cancer deaths were observed with 57 expected, making a standardized mortality ratio of 98 percent.

Significantly less lung cancer might be expected because of the overall cancer deficiency and the favorable social class gradient observed for

Table 46. Observed and expected deaths from lung cancer, 1931–60 [a]

Year	Observed	Expected	S.M.R.	Z
1931–35	4	3	133	0.5
1936–40	4	5	80	0.5
1941–45	4	8	50	2.0
1946–50	11	12	92	0.3
1951–55	24	20	120	0.8
1956–60	21	25	84	0.9
1931–60	68	73	93	0.6

[a] The following rubrics of the appropriate International Revisions have been included:
1931–38 47 b, c
1939–48 47 b–f
1949–60 160, 162, 163
These were also utilized in the construction of rates from which expected deaths were calculated.

lung cancer around 1950 in the United States and Great Britain. British physicians also showed less than expected deaths from lung cancer. However, New England dentists have experienced about the same lung cancer mortality as the general population.

CANCER OF THE DIGESTIVE ORGANS

Table 47 shows observed and expected deaths from cancer of the digestive organs. Expected numbers were calculated from New England standard rates. In all time periods, dentists experienced fewer deaths than expected from cancer of the digestive organs. Standardized mortality ratios were statistically significant except for 1921–25 and 1956–60. During this latter period, more than 10 percent of the cohort was over age 69. More than one-half of the deaths from cancer of the digestive system were in this over 69-age group. However, the mortality ratio for 1956–60 approaches statistical significance. The mortality ratio of 66 percent for the entire study period is highly significant.

It has been reported that mortality from cancer of the stomach is lower in higher socio-economic groups than in the general population; the opposite is true for cancer of the intestines. These relations were tested in cohort cancer deaths that occurred during 1946–55. Age-specific rates effective for the midpoint of this period were calculated by dividing appropriate white male population values from the 1950 census into the corresponding numbers of white male deaths in the same year from cancer of the stomach (Title 151), and cancer of the intestines (Titles 152, 153). Expected deaths of dentists from these causes were calculated from the above rates and 1946–55 cohort person-years at risk. The results of this comparison are shown in table 48. Observed deaths due

Table 47. Observed and expected deaths from cancer of the digestive organs

Year	Observed	Expected	S.M.R.	Z
1921–25	18	23	78	1.2
1926–30	14	31	45	4.5
1931–35	31	45	69	2.5
1936–40	28	43	65	2.8
1941–45	31	50	62	3.4
1946–50	30	56	54	4.8
1949–53	37	55	67	3.0
1951–55	40	55	73	2.4
1956–60	43	54	80	1.7
1921–60	235	357	66	8.0

Table 48. Observed and expected deaths from cancer of the stomach and intestines 1946–55

Cancer of:	Deaths		S.M.R.	Z
	Observed	Expected [a]		
Stomach [b]	18	30	60	2.8
Intestines [b]	24	22	109	0.4

[a] From U.S. standard rates.

[b] The following rubrics of the appropriate International Revisions have been included:
Cancer of the stomach: 1946–48, 46b, 1949–55, 151
Cancer of intestines: 1946–48, 46c, e; 1949–55, 152, 153

to stomach cancer are significantly less than those expected from U.S. standard rates. The standardized mortality ratio of 60 percent is highly significant ($p<0.01$). However, the ratio of 109 percent obtained for cancer of the intestines demonstrates that deaths from this cause approximated those expected.

Standardized mortality ratios for stomach and intestinal cancer by social class for 1949–53 in England and Wales are shown in table 49 (*69*). A similar association for stomach cancer was observed for U.S. white males in the 1950 Occupational Mortality Study; however, the gradient for intestinal cancer, although inverse, was not as strong or as consistent as that observed in England (*62*).

Table 49. Standard mortality ratios for cancer of the stomach and intestines, white males, age 20–64, England and Wales, 1949–53 [a]

Cancer of:	Social Class				
	I	II	III	IV	V
Stomach	57	70	101	112	130
Small intestine	122	120	96	86	108
Large intestine	121	101	102	92	99

[a] Reference *69*.

While mortality from intestinal cancer during 1946–55 equaled that of the standard, deficiencies in stomach and other cancers were sufficiently large to result in an overall, significant deficiency in cancer of the digestive system as a whole.

MORTALITY FROM CARDIOVASCULAR RENAL DISEASE

HEART DISEASE

Observed and expected deaths from heart disease are shown in table 50. Mortality ratios for year periods and the total are close to 90 percent except during the early years of the study. For the 40-year period, there is a significant ratio of 91 percent. Without the data of the period 1921–30, the ratio is still significant. However, heart disease has accounted for more than 40 percent of all deaths occurring during the entire study period.

In order to eliminate the effect of the open-ended age group, analyses were repeated for the age group 20–69. This procedure resulted in mortality ratios close to 100 percent, as seen in table 51. Except for the period 1921–30, none of these ratios is statistically significant. Thus, in spite of favorable mortality from all causes, dentists have suffered about the same mortality from heart disease as the general population.

Utilizing the New England specific heart disease death rates of 1949–51, a standardized mortality ratio of 103 percent is observed for dentists during 1949–53 for those groups under age 65 (*56*). The U.S. 1950 Occupational Mortality Study reported the following ratios for heart disease in the age group 20–64:

U.S. professional workers	102 percent
U.S. dentists	102 percent

During the same period British dentists showed significantly excess mortality from heart disease. During 1949–53, New England dentists

Table 50. Observed and expected deaths from heart disease

Year	Observed	Expected	S.M.R.	Z
1921–25	64	82	78	2.2
1926–30	85	115	74	3.2
1931–35	160	180	89	1.6
1936–40	215	216	100	0
1939–43	239	248	96	0.6
1941–45	245	261	94	1.0
1946–50	287	313	92	1.5
1949–53	316	339	93	1.3
1951–55	321	357	90	2.0
1956–60	340	369	92	1.6
1921–60	1,717	1,893	91	4.2

Table 51. Observed and expected deaths, age 20–69 from heart disease

Year	Observed	Expected	S.M.R.	Z
1921–25	40	54	74	2.2
1926–30	53	73	73	2.7
1931–35	106	116	91	1.0
1936–40	143	131	109	1.0
1941–45	156	149	105	0.6
1946–50	163	160	102	0.2
1951–55	163	172	95	0.7
1956–60	179	173	103	0.4
1921–60	1,003	1,028	98	0.8

experienced almost the same mortality as all U.S. dentists and professional workers.

During the last 20 years of this study, those dentists under age 70 have demonstrated mortality from heart disease equal to that of the general population. This is in marked distinction to deaths from all causes and all forms of cancer.

VASCULAR LESIONS AFFECTING THE CENTRAL NERVOUS SYSTEM (STROKE)

Analyses of observed and expected deaths from vascular lesions affecting the central nervous system (stroke) are shown in table 52. This cause has ranked third in order of significance in this study. Only during the early study years was a significant deficiency observed. During the period 1956–60, a significant excess was registered. Deaths occurring under age 70 are shown in table 53. Here many of the mortality ratios are up to or in excess of 100 percent. During the period 1956–60, mortality from stroke with 100 observed deaths almost matched that of cancer with 119 deaths.

Table 52. Observed and expected deaths from vascular lesions affecting the central nervous system

Year	Observed	Expected	S.M.R.	Z
1921–25	33	41	80	1.4
1926–30	28	45	62	3.2
1931–35	45	53	85	1.2
1936–40	43	50	86	1.1
1939–43	48	56	86	1.2
1941–45	49	56	88	1.0
1946–50	68	64	106	0.5
1949–53	78	74	105	0.5
1951–55	71	77	92	0.7
1956–60	100	80	125	2.0
1921–60	437	466	94	1.4

In order to compare mortality from stroke with results of the 1950 U.S. Occupational Mortality Study, analyses were repeated for the period 1949–53, calculating expected values from New England standard rates for the age group 20–64. During 1949–53, 27 deaths from stroke were observed with 18 expected, age 20–64. This results in a standardized mortality ratio of 150 percent, which approaches significance at the 5

Table 53. **Observed and expected deaths, age 20–69, from vascular lesions affecting the central nervous system**

Year	Observed	Expected	S.M.R.	Z
1921–25	23	24	96	0.2
1926–30	13	26	50	3.6
1931–35	36	31	116	0.8
1936–40	25	26	96	0.2
1941–45	28	27	104	0.2
1946–50	39	26	150	2.1
1951–55	29	27	107	0.4
1956–60	30	26	115	0.7
1921–60	223	213	105	0.7

percent level. The 1950 U.S. Occupational Mortality Study lists the following mortality ratios for stroke (*61*):

All U.S. professional workers	87 percent
U.S. dentists	104 percent
U.S. physicians and surgeons	102 percent.

The ever increasing significance of cardiovascular disease has been well established in mortality studies. This results in part from benefits obtained in the control over other diseases. However, the tendency observed in this study toward excess mortality from stroke may represent a real surplus also amenable to control.

ARTERIOSCLEROSIS

Observed and expected deaths from arteriosclerosis are shown in table 54. Except for the first and last 5-year periods, a significant deficiency of deaths has been observed. Few deaths under age 70 have been recorded from arteriosclerosis. According to Dublin (*77*), little significance can be attached to data in this title, since they probably represent cases of heart disease or cerebral hemorrhage, in which typical signs of the latter entities were not evident. In 1950, all U.S. professional workers reported a standardized mortality ratio of 56 percent, the same reported for this study in 1951–55, and the entire period. In England and Wales, no distinct social class gradient has been observed. The deficiencies in numbers of deaths reported for this cause may evidence better medical care and more accurate diagnosis of other cardiovascular disease rather than different mortality experience.

Table 54. Observed and expected deaths from general arteriosclerosis

Year	Observed	Expected	S.M.R.	Z
1931–35	15	17	88	0.5
1936–40	5	14	36	4.0
1941–45	4	13	31	4.5
1946–50	5	16	31	4.9
1949–53	9	19	47	3.3
1951–55	10	18	56	2.5
1956–60	14	16	88	0.5
1931–60	53	94	56	5.6

CHRONIC NEPHRITIS

Observed and expected deaths from chronic nephritis are listed in table 55. The most striking feature of this distribution is the consistent decline in numbers of expected deaths. This decline illustrates the problem sometimes present in the study of secular trends in mortality. The decline in death rates for chronic nephritis has been largely due to

Table 55. Observed and expected deaths from chronic nephritis

Year	Observed	Expected	S.M.R.	Z
1921–25	28	33	85	0.9
1926–30	24	42	57	3.7
1931–35	35	43	81	1.4
1936–40	27	43	63	3.1
1939–43	27	44	61	3.3
1941–45	23	45	51	4.6
1946–50	19	36	53	3.9
1949–53	3	9	33	3.5
1951–55	2	7	29	3.5
1956–60	4	5	80	0.5
1921–60	162	254	64	7.2

changing methods of classifying causes of death plus revisions in diagnostic concepts. Many deaths in the past attributed to chronic nephritis would be presently classified in the heart disease category, due to changes in thinking about the relation of these disorders to hypertension.

Mortality from chronic nephritis has been consistently lower than expected from general population rates. The overall experience has been one of a significant deficiency. Only during 1956–60 have observed deaths approximated those expected. The observed deficiencies are consistent with findings of the 1950 U.S. Occupational Mortality Study relating to all professional workers.

MORTALITY FROM OTHER CAUSES

TUBERCULOSIS (ALL FORMS)

Findings for tuberculosis are shown in table 56. A major feature here is the steady drop in numbers of both expected and observed deaths. Observed tuberculosis mortality has averaged 39 percent of that expected over the study period, with all ratios highly significant. Low tuberculosis mortality has long been associated with high socio-economic status. Distinct social class gradients were reported for England and Wales

Table 56. Observed and expected deaths from tuberculosis (all forms)

Year	Observed	Expected	S.M.R.	Z
1921–25	12	38	32	7.5
1926–30	15	35	43	5.2
1931–35	15	32	47	4.4
1936–40	9	23	39	4.7
1939–43	11	22	50	3.3
1941–45	10	24	42	4.4
1946–50	8	21	38	4.6
1949–53	3	16	19	7.5
1951–55	3	11	27	4.6
1956–60	2	7	29	3.5
1921–60	74	191	39	13.6

during 1921–23, 1930–32, and 1949–53. The consistent deficiencies of observed deaths are not so much owing to the dentist's occupation, as to his earlier health and socio-economic status that permitted him to select this profession.

During 1949–53, New England dentists under age 65 showed a mortality ratio of 19 percent, while all U.S. professional workers experienced 36 percent of expected mortality. Tuberculosis mortality has exhibited considerable geographic variation, with the New England region in recent years demonstrating relatively low rates. The combination of high socio-economic status and geographic location has, in recent years, resulted in an extremely favorable mortality experience for New England dentists.

INFLUENZA AND PNEUMONIA

Mortality data for influenza and pneumonia are shown in table 57. These causes of death were combined in order to obtain the maximum degree of comparability among the periods of use of different methods for classifying causes of death. These are often grouped together because of their similar location anatomically and sudden onset. Furthermore, pneumonia may often follow an attack of influenza.

The vast majority of deaths in these categories has been due to pneumonia. Influenza deaths during the first half of the study numbered 15; during the second half only 3. Mortality from influenza was low.

Table 57. Observed and expected deaths from influenza and pneumonia

Year	Observed	Expected	S.M.R.	Z
1921–25	22	36	61	3.0
1926–30	20	44	45	5.4
1931–35	28	46	61	3.4
1936–40	30	36	83	1.1
1939–43	20	28	71	1.8
1941–45	22	29	76	1.5
1946–50	13	19	68	1.7
1949–53	7	16	44	3.4
1951–55	13	17	76	1.1
1956–60	13	24	54	3.0
1921–60	161	251	64	7.1

Observed deaths were consistently less than expected for the influenza and pneumonia death rates of the general population. Expected deaths decreased steadily from 1930 until the 1956–60 period, which was characterized by an upswing in expected deaths owing to the influenza epidemics of 1957–58 and 1960.

For the entire study period and certain 5-year periods, observed deficiencies are statistically significant. Certainly mortality from these communicable diseases does not appear to have been increased by dentists' close contact with patients. However, no conclusions concerning morbidity are in order.

Unlike dentists in this study, U.S. physicians in 1925 and 1938–42 experienced excess mortality from influenza and pneumonia. This surplus was also reported for British physicians. By 1950, mortality for U.S. and British physicians had decreased to less than general population standards. The Registrar-General of England and Wales recorded consistently a social class gradient for pneumonia and influenza, favoring those of higher socio-economic status. A similar gradient was observed in the United States in 1950. The influenza mortality of British dentists was similar to that of the general population, although pneumonia deaths were less than expected.

Mortality from influenza and pneumonia rises sharply after age 50 and might be expected to result in surplus deaths in this study because of the steadily increasing numbers in the older age groups. Instead, deficient mortality has been observed, probably related to high socio-economic status and availability of adequate medical care.

ULCER OF THE STOMACH AND DUODENUM

Observed and expected deaths from ulcer of the stomach and duodenum are shown in table 58. The numbers of deaths involved are relatively low. Findings here have been the least consistent of those causes of death studied. While some time periods have produced significant deficiencies of deaths from ulcers, the overall result is not statistically significant. On the basis of the experience of U.S. physicians and upper socio-economic groups in this country and England, a greater deficiency of deaths would be expected. Actually, the finding for this study during 1949–53 of a significant deficiency of deaths is the only one consistent with other recent studies.

CIRRHOSIS OF THE LIVER

The distribution of observed and expected deaths from liver cirrhosis is shown in table 59. During the entire period of study, observed deaths approximated those expected from the rates of the general New England white male population. However, during the last half of the study, observed deaths numbered 54 with 39 expected, forming a standardized mortality ratio of 138 percent, which is significant at the 5 percent level.

Table 58. Observed and expected deaths from ulcer of stomach and duodenum

Year	Observed	Expected	S.M.R.	Z
1921–25	2	4	50	1.4
1926–30	2	6	33	2.8
1931–35	7	7	100	0
1936–40	7	7	100	0
1941–45	5	8	62	1.3
1946–50	4	8	50	2.0
1949–53	2	8	25	4.2
1951–55	8	9	89	0.4
1956–60	12	8	150	1.2
1921–60	47	57	82	1.5

Table 59. Observed and expected deaths from cirrhosis of liver

Year	Observed	Expected	S.M.R.	Z
1921–25	2	3	67	0.7
1926–30	2	4	50	1.4
1931–35	5	6	83	0.4
1936–40	6	7	86	0.4
1941–45	15	9	167	1.6
1946–50	15	10	150	1.3
1949–53	16	10	160	1.5
1951–55	11	11	100	—
1956–60	13	9	144	1.1
1921–60	69	59	117	1.2

Mortality from liver cirrhosis around 1950 has been reported to be inversely related to socio-economic status in the United States and directly related in England and Wales. However, U.S. physicians have experienced about the expected mortality, while British physicians and dentists have demonstrated surplus mortality. Although all U.S. white professional workers showed a standardized mortality ratio of 91 percent for cirrhosis in 1950, not all occupations making up the group were consistent in this respect. Physicians, lawyers, judges, pharmacists, authors, and editors all exhibited mortality in excess of that expected. Mortality for dentists from liver cirrhosis, therefore, has been consistent with that observed in the professions in the United States as well as England and Wales.

DIABETES

Table 60 shows that mortality from diabetes has approximated general population standards. While ratios were recorded below 100 percent, none are statistically significant. During the last half of the study, observed deaths almost matched those expected.

The decline in numbers of expected deaths after 1945 is due to changes in the technique of classifying deaths. The decline would be sharper were the cohort not enlarging in the older age groups, which are supplying most of the deaths from diabetes.

U.S. physician mortality from diabetes has equaled (1938–42) or exceeded (1949–51) that of the general population. In 1950, all U.S. professional workers showed a mortality ratio for diabetes of 98 percent. In England, the first social class has demonstrated high mortality ratios from this cause. Thus, these findings for dentists are again consistent with those previously reported for professional and upper socio-economic groups.

Table 60. Observed and expected deaths from diabetes

Year	Observed	Expected	S.M.R.	Z
1921–25	11	6	183	1.5
1926–30	10	7	143	1.0
1931–35	9	12	75	1.0
1936–40	11	13	85	0.6
1939–43	12	15	80	0.9
1941–45	19	14	136	1.2
1946–50	10	13	77	1.0
1949–53	11	11	100	—
1951–55	12	11	109	0.3
1956–60	11	11	100	—
1921–60	93	87	107	0.6

ACCIDENTS

Observed and expected deaths from accidents are shown in table 61. Expected deaths from accidents have decreased steadily since 1935, reflecting the sharp decline in accidental death rates (age-adjusted) since that time. Until 1956–60, the deficiency in observed accidental deaths was one of the largest and most consistent observed in this study. For the entire period and each 5-year interval except the last, the deficiencies were highly significant. New England dentists have consistently experienced only one-half of the deaths expected from general population rates.

During 1956–60, the standardized mortality ratio was 39 percent and not statistically significant. Limiting the analysis to those under age 70 provided a similar result. Thus, the change was not the result alone of the expanding older age group, which experience high death rates.

During the period 1949–53, dentists under age 65 showed a mortality ratio of 38 percent. This compares favorably with a 1950 ratio of 53 percent for all U.S. dentists, 61 percent for physicians, and 50 percent for all professional workers of the same age.

No accidental deaths have been reported as associated with dentists' working activities. A considerable part of the deficiency of accidental deaths in professional workers is derived from the absence of on-the-job accidents. Professional work in general is associated with minimal risk of work accidents. This deficiency has also been observed among dentists in England and Wales.

Table 61. Observed and expected deaths from accidents

Year	Observed	Expected	S.M.R.	Z
1921–25	7	29	24	8.3
1926–30	13	34	38	5.8
1931–35	24	43	56	3.9
1936–40	17	35	49	4.4
1939–43	16	37	43	5.2
1941–45	16	35	46	4.8
1946–50	14	32	44	4.8
1949–53	15	31	48	4.1
1951–55	15	31	48	4.1
1956–60	25	28	89	0.6
1921–60	131	267	49	11.9

SUICIDE

The distribution of observed and expected deaths from suicide is shown in table 62. This is the only cause of death with an excess approaching (p = 0.06) statistical significance over the entire study period. Only two time intervals failed to demonstrate suicides equal to or greater than those expected. During the first half of the study period, the 48 suicides reported exceeded those expected by only 4. However, during the second half, the 52 recorded and 37 expected suicides produced a standardized mortality ratio of 141 percent, which is significant at the 5 percent level.

During the period 1931–35, suicides were only 86 percent of those expected. However, MacMahon *et al.* have found that suicide rates for the general population reached a peak during the height of the depression, 1933 (*78*). Therefore, the findings for dentists appear to be inconsistent with those of the general population. However, mortality from suicide was known to be high in professional groups in general and dentists in particular in the United States and England (*57*, *59*, *62*, *68*, *69*, *79*). For this reason and because professional workers may be more skilled in concealing suicide, accidental deaths during 1931–35 were reviewed for specific cause.

During the 1931–35 interval, seven deaths were presumed accidental (according to death certificates), yet might well have been suicides. All of these presumed accidents occurred among dentists under age 60; of these, three were due to the ingestion of drugs and four were due to asphyxiation. Death by suicide carries an associated stigma of mental

Table 62. Observed and expected deaths from suicide

Year	Observed	Expected	S.M.R.	Z
1921–25	7	8	88	0.4
1926–30	13	10	130	0.8
1931–35	12	14	86	0.6
1936–40	16	12	133	1.0
1941–45	11	9	122	0.6
1946–50	10	10	100	—
1949–53	17	10	170	1.7
1951–55	18	9	200	2.1
1956–60	13	9	144	1.1
1921–60	100	81	123	1.9

illness. The person committing suicide, his family, or physician may attempt to conceal this by labeling a suicide as an accident. While this is speculative, it provides a basis for suspecting more suicides than so certified during this period. This concealment plus simulated automobile accidents would tend to produce underreporting of suicide.

To test the hypothesis of actual suicides having been recorded as accidental deaths, the following procedure was carried out. Age-specific accidental death rates of the study cohort were computed for the study period by dividing total age-distributed person-years at risk into total numbers of age-distributed accidental deaths. These rates were used to make intracohort comparisons by predicting expected accidental deaths in each 5-year period. The expected numbers of accidental deaths were similar to observed deaths in each 5-year period, except during 1931–35. Here, 24 deaths were observed with 14 expected, the difference being significant at the 5 percent level. This finding supports the possibility that at least some of the deaths presumed accidental may have been suicidal.

In a recent study of suicide among professional workers in Oregon, the suicide rate of attorneys, physicians, and dentists was three times that of white collar workers. The dentists' rate was the highest (*79*). Dentists in England and Wales have shown high suicide mortality, with ratios of 178 and 270 percent reported for 1930–32 and 1949–53, respectively.

According to Dublin, suicide is an "action indicative of a badly integrated personality—one unable to withstand the ordinary strains and stresses of life . . . the end result of personal maladjustments and frustrations . . . ." (*80*). This concept is an oversimplification of a complex phenomenon influenced by the temperament of the individual committing suicide, his mental health, cultural attitudes prevalent in his society, and a multitude of situations over which the individual may or may not have any control.

A basic question, seemingly unanswered, is whether a profession confers the additional risk of suicide or attracts from the general population a high proportion of individuals possessing those personality traits that predispose to suicide. Professional people are self-selected, specially educated, and different in many respects from the general population.

Declines in suicide rates for all males have been observed during periods of war and full employment. A striking illustration was evident in the United States during World War II and the periods immediately preceding and following. From the time of industrial mobilization in 1939 until 1943, male general population suicide rates for selected age groups dropped markedly, only to increase as sharply while employment competition increased after the war (*78*).

During the 1941–45 period of this study, the decline described above was reflected in a decrease in the number of suicides expected among cohort members, compared to the 1936–40 period. However, observed suicides were still in excess of those expected during these war years. All suicides except one, during 1941–45, occurred under age 69. The number of dentists in practice during the war dropped precipitously due to deaths, exits to the Armed Forces, and the entry of new dental school graduates into military service rather than private practice. Dental appointments were then at a premium. This was indeed an era of full employment for New England dentists.

During 1946–50, when the general population suicide rates were generally rising (age groups over age 34), expected and observed number of suicides in this study were the same. While the differences among the standardized mortality ratios for suicide for the periods discussed above are not statistically significant, they warrant the suggestion that factors precipitating suicide may differ from those operating among the general population.

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